STATE OF ENVIRONMENT IN ORISSA-II

THE ATMOSPHERE

R C DAS

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STATE PREVENTION AND CONTROL OF POLLUTION BOARD, ORISSA

Editorial Board for the Preparation of the State of Environment Report for Orissa

Cover Design by Sri C. R. Nayak, Research Analyst, S P C P Board, Bhubaneswar.

AUTHOR'S NOTE

The general reactions of the readers on the first volume of the State of Environment of Orissa on Water Resources has encouraged me to venture into writing the second volume in spite of the availability of much less input materials.

Except ths rainfall, no other climatic parameter of Orissa like the temperature, humidity, atmospheric pressure etc has been systematically studied. The present concern about the global climatic change due to phenomena like the greenhouse effect, ozone leak and massive deforestation should make us keep a close watch on all our climatic parameters. Yet no scientist in the State seems to be seriously studying this—at least to the best of our knowledge. Information available on the atmospheric pollution level is meagre. Wherever available, they are not complete and systematic, but patchy. The State Pollution Control Board has measured the air quality only at a few places for its regulatory purposes and not for any serious study—mainly due to the lack of resources. No scientific study has been made to reconcile the controversy between the Archaeological Survey of India and a scientist belonging to an educational institution on the state and cause of decay of archaeological monuments in the state, particularly the Sun temple at Konarak.

The readers can well imagine the difficulty in preparing this report because of inadequacy of information. Yet I have tried to give a comprehensive picture of the status of the atmosphere in the State I have tried to refrain from taking sides in certain controversies. All points of view have been presented for an intelligent reader to draw his own conclusions.

Apart from all members of the Editorial Board, I am grateful to Dr C. R Das, Reader in Chemistry, Ravenshaw College, Cuttack, Sri C. V. Krishna, presently working in Ehiopia as an energy expert on deputation from tde Government and many others with whom I had valuable discussions. The help rendeied by Dr L. N. Patnaik and his team of scientists, particularly Shri P K. Prusty, Shri D.K Behera, Shri D. K. Rout & Shri C. Nayak were invaluable.

(R. C. Das)

EDITORIAL

The Department of Science, Technology and Environment, Government of Orissa entrusted the State Prevention & Control of Pollution Board the task of preparing a comprehensive report on the State of Environment of Crissa. The report would cover the following four components at the first instance : i) Water Resources ii) Atmosphere, iii) Industrial and Mining Scene and iv) Energy Scene.

The first volume on Water Resources was released on the February 1, 1989 by Shri Sk. Matlub Ali, Hon'ble Minister of Irrigation, Power and Parliamentary Affairs during the inauguration of an International Seminar on the "Environmental Impact of Industrial and Mining Activities," organised by the Board. The comments and opinions so far received from various experts are quite appreciative, encouraging and educative

The present report on the "State of Environment of Orissa (Vol-II) — Atmosphere" essentially deals with three aspects—the climate, the state of atmospheric pollution and the present state of our archaeological monuments. The climate and climatic changes of a place are too vast and complex as a subject and cannot be discussed strictly within the local geographical framework. Hence, certain phenomena like greenhouse effect and depletion of ozone layer have been discussed in some detail so that the atmospheric and climatic changes taking place in Orissa can be appreciated better vis-a vis the global scene.

To the extent possible, we have tried to project all conflicting views on certain subjects without any favour for or bias against a particular hypothesis/theory. It is left to the reader to draw conclusion. However, ***wherever any definite view has been expressed, it is the author's own and not necessarily the official view of the S P C P Board or the State Government.***

In keeping with the earlier practice, we have co opted Shri R. K Sharma, Superintending Archaeological Chemist, Archaeological Survey of India, Bhubaneswar, as a member of the Editorial Board for this volume.

We are grateful to the Department of Science, Technology and Environment for the necessary financial and material support.

Editors

INTRODUCTION

The envelope of gases around the earth is called the ***atmosphere***. Many living organisms on earth, including man, require oxygen for life which is obtained from the atmosphere either directly or indirectly. The atmosphere not only provides the oxygen required, it also shapes the climate and other environmental conditions necessary for the sustenance of life.

The Different Layers

The atmosphere extends to a height of about 20C0km from the earth's surface It can be divided into several layers depending upon the characteristic chemical species present, temperature profile and other physical and chemical behaviours (Table 1, Fig 1).

Table 1
Major Regions of the Atmosphere [1]

Region	Altitude Range (km)	Temperature Range(°C)	Important Characteristic Chemical Species
Troposphere	0 to 11	15 to −56	N_2, O_2, CO_2, H_2,
Stratosphere	11 to 50	−56 to −2	O_3
Mesosphere	50 to 85	−2 to 92	O_2^+, NO^+
Thermosphere	85 to 500	92 to 1200	O_2^+, O^+, NO^+

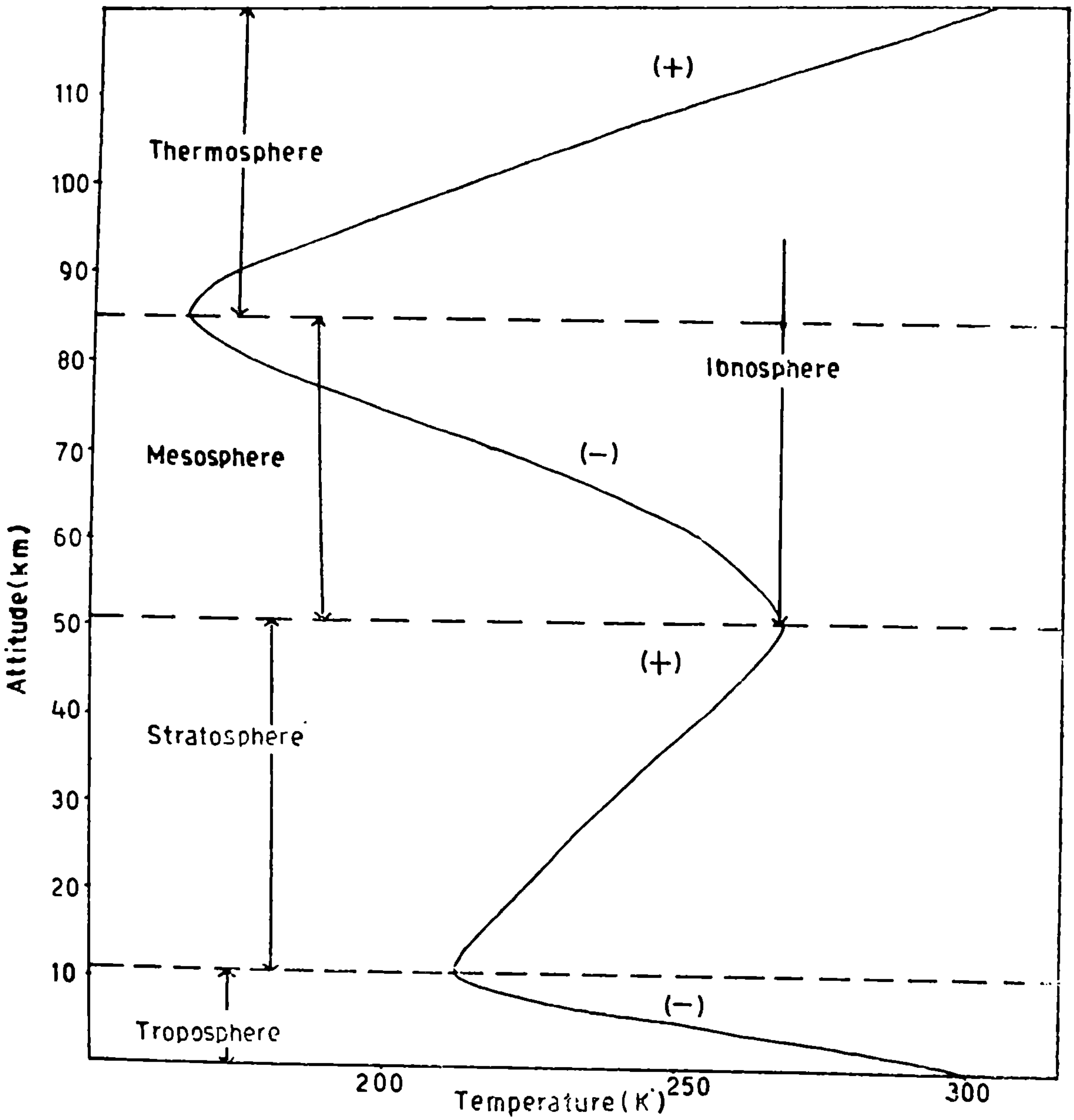

Fig. 1 The different layers in the atmosphere.

About 70% of the total mass of the atmosphere is mostly confined within about 11km altitude. This layer is called the *troposphere* Clouds, rains, snow, wind and all other natural meteorological phenomena take place only within the troposphere. Since almost all human activities are confined to this region, the pollutants generated by such activities are mostly present in this layer.

The *stratosphere*, just above the troposphere, is a quiescent layer. The ozone gas present in this protects us from intense ultraviolet radiation from the sun, as well as, from cosmic radiation from the outer space. However, slow diffusion of certain pollutants from the troposphere and also direct emissions from space ships etc have recently resulted in what is called the *"ozone leak"* posing direct threat to human life which will be discussed later. Being a quiescent layer, pollutants tend to have a longer residence time in this layer than in the troposphere where rains, snow etc periodically clean the atmosphere.

The atmosphere near the surface of earth contains about 78.09 per cent of nitrogen gas and about 20.24 per cent of oxygen gas. The remaining amount consists of water vapour, carbon dioxide and many other gases in trace amounts including pollutants released into it.

Atmospheric Pollutants

Pollutants in the atmosphere can be classified into two categories, viz. *primary pollutants* and *secondary pollutants*. In the first category are those gaseous pollutants which are directly released into the atmosphere as a result of direct anthropogenic activities. These are mostly the products of combustion of fossil fuels (carbon dioxide, carbon monoxide, sulphur dioxide, oxides of nitrogen etc), other specific pollutants released by specific activities (e. g., solvent vapours, ammonia, hydrogen fluoride, chloro-fluoro carbons etc) and particulate matters (smoke, dust etc). Besides, many natural processes also produce atmospheric pollutants. For example, bacterial decay of organic matters generate methane, carbon dioxide, ammonia, sulphides etc depending upon the nature of the substrate and the type of bacteria in action. Respiration of plants and animals produce carbon dioxide. Carbon dioxide, although beneficial to plants and not physiologically harmful to man at the level in which it is released into the atmosphere may have far reaching effects on the global climate. This will be discussed in a subsequent part of this report. Carbon monoxide, formed as a result of incomplete combustion of coal or petroleum, is definitely a poisonous gas, because it interferes with the oxygen-carrying process of haemoglobin of blood. Sulphur dioxide is produced during combustion of fossil fuels, because such fuels always contain some amount of sulphur. This is an acidic gas and finally gets converted to sulphuric acid in the atmosphere which is responsible for the so-called *"acid rain"* in the industrialised world. Acid rain is particularly harmful for vegetation. Apart from being the main cause of acid rain, sulphur dioxide is also a health hazard and further, it corrodes metallic, concrete and other structures because of the acidic nature. Oxides of nitrogen, combinedly called *"Knox"* (NO_x) by pollution scientists, are products of high temperature combustion of fossil fuels. Automobile emission is the main contributor of NO_x in the urban atmosphere followed by emission of thermal power plants. Knox is primarily responsible for photochemical smog formation in metropolitan areas. Particulate matters in the atmosphere are of great nuisance. Many respiratory problems can be attributed to smoke and dust in the atmosphere. Small particles in the atmosphere, called *aerosols*. have important role in many atmospheric phenomena (cloud formation, providing catalytic surface for some atmospheric chemical reactions etc .

Secondary pollutants are the products of atmospheric reactions initiated by the primary

pollutants. Because of the large excess of oxygen in the atmosphere and the plenty of sunlight available, the atmospheric reactions are mainly photochemical oxidation reactions. Secondary pollutants consist of a wide variety of organic and inorganic compounds many of which are toxic. *Smog in metropolitan cities contain secondary pollutants.*

Global Climatic Change

Carbon dioxide helps to keep the warmth of the atmosphere by absorbing the scattered sunlight from the earth's surface in the same way the glass or plastic cover maintains the temperature inside greenhouses of farms in cold countries. The warming up of the atmosphere by carbon dioxide and similar gases is, therefore, called the *greenhouse effect*. Without going through the complicated physical and chemical principles the greenhouse effect can be explained in a very simple manner in the following way.

The solar radiation falling on the earth mainly consists of visible light within a small range of wavelength (peak around 600 nm*) and energy. Part of it is reflected into the space from the outer atmospheric surface and clouds etc (app 25%) and from the earth's surface (app 6%). The remaining amount is absorbed by the atmosphere (app 23%) and the surface of earth consisting of land and sea (app 46%). The light absorbing matters of land, sea and atmosphere get warmed up by the solar radiation and in the process emit radiations by a well-known physical phenomenon called the *"black body radiation"*. Considering the average temperature of the earth's surface, the emitted radiation belongs to the far-infrared region (peak around 1600 nm*). Greenhouse gases like carbon dioxide which are present in the atmosphere, because of their specific chemical structures, partly absorb the infrared radiation and cause further warming up of the atmosphere. A part of the heat acquired by the atmospheric gases by the aforesaid processes is used for the transport of gases in convection currents, and a part of it also is transmitted back to the space in the form of infrared emissions generated from the heated gases. Although the greenhouse effect warms up the atmosphere, continuous heating does not take place because the heat balance in the atmosphere is maintained through many complex interactions within it.

Carbon dioxide is the most important of the greenhouse gases in the atmosphere. Other greenhouse gases include nitrous oxide, methane, ozone, methyl chloroform, carbon monoxide, carbon tetrachloride, chloro-fluorocarbons (CFC 11 and CFC 12) etc present in trace quantities. Level of carbon dioxide in the atmosphere has increased by about 25% since the Industrial Revolution - from about 270 parts per million by volume (ppmv) to a present level of about 344 ppmv. But recent years have experienced accelerated increase of carbon dioxide in the atmosphere due to the combined effect of increased use of fossil fuels and rapid loss of the forest cover which used to act as a sink for atmospheric carbon dioxide (plants take carbon dioxide for photo-synthesis). If the present trend continues, there may be a further increase of carbon dioxide in the atmosphere by about 30% more in the next 50 years (by 2330AD) and the consequent greenhouse warming. Besides, concentrations of other trace greenhouse gases like methane, nitrous oxide and CFC's are likely to increase at a much faster rate than carbon dioxide. Although these gases will still be in very trace amounts and certainly much less in quantity than carbon dioxide after the next half-century, their greenhouse effect will be almost same as that of the carbon dioxide present in the atmosphere [*2*, *3*].

As already mentioned, ozone is an important species in the atmosphere and acts as a protective

*1nm = 10^{-9} m

radiation shield for organisms on the surface of the earth It strongly absorbs ultraviolet light (in the region 220-330 nm) for which only a small fraction of the ultraviolet light reaches the lower atmosphere In the natural process, ozone is formed and destroyed in the atmosphere through complicated photochemical reactions. Consequently, an equilibrium concentration is maintained. The maximum ozone concentration in the stratosphere is about 10 ppmv at an altitude of 25-30km Some of these diffuse down to the lower troposphere to have a ground level concentration of about 0.01 ppmv. Several chemicals used in or produced by industry help the breakdown process of ozone in the atmosphere. These include the CFC's, already mentioned, which are used as propellants in aerosols, in refrigeration technology, as foam-blowing agents in plastic industry etc. Other gases that speed up break down of ozone include nitrous oxide and those containing fluorine, chlorine and bromine. These chemicals are now increasingly being released into the atmosphere because of various industrial activities. Some calculations show that because of the increasing concentration of the above gases, the ozone level may fall by a few percent, even upto 10%, during the first half of the next century. Recent measurements show that no appreciable change has taken place as yet in the total amount of ozone in the atmosphere although small changes seem to have started occurring at particular heights with low level ozone concentrations increasing and the high level ones decreasing. But surprisingly the ozone concentration over Antarctica seems to have decreased by about 40% over the 1957 level. No viable explanation is available for this extra ordinary phenomenon termed as the "*ozone leak*" [4].

The greenhouse effect and the ozone depletion should not be viewed as separate and independent problems. Ozone changes will also affect the climate as ozone itself is a greenhouse gas and also carbon dioxide changes can influence ozone depletion.

The question now arises is how far the greenhouse warming will take place in future, say within the next 50 years and how it will affect the eco-system. Different models by different experts give different predictions as is expected from such futuristic predictions. The models suggest that earth's average surface temperature would increase between 1.5 to 4.5°C. In fact, the range of results from three most recent models is between 3.5 to 4.2°C. The warming will be most marked in the northern hemisphere in winter and in high latitudes. In the southern hemisphere, maximum warming will be in Antarctica.

This global warming is bound to have profound influence on the climate considering the fact that earth's average temperature has very rarely varied by 1 to 2°C in the last 10,000 years. Earth's average temperature during the most recent ice age was only about 5°C colder than what it is now. Although exact predictions about the climate and other environmental changes due to the expected warming is difficult, some conjectures, based on the existing observations, can be made. Higher atmospheric temperature would mean more evaporation and consequently increased rain. The global rainfall may increase by 7 to 10% by 2040 AD, but the geographical distribution of rainfall may change. More rains in the tropics but increased draught conditions in the subtropics is a possibility. Further, increased rate of evaporation may lead to drier soils in wide areas which may affect agricultural pattern. Existing crop fields in the subtropic regions may tend to shift towards the poles. Grasslands and deserts are likely to increase in area and forested area may dwindle further.

More carbon dioxide in the atmosphere may help tree growth because of increased photosynthetic activities of the plants. Trees will become larger in size. Alongwith the plants, weeds will also tend to grow faster and easier and thus, compete with agricultural and other

commercial crops. There is a possibility of overall increase of crop yield in the world within the next 50 years but that will require much greater use of fertilisers and pesticides and further, it will not be without serious disruption of the existing geographical pattern of crop production. For example, crops like maize, sorghum, millet and sugarcane may not respond to increased carbon dioxide concentration in the atmosphere as favourably as other crops like wheat, rice etc. Unfortunately these are the main crops in some of the poorest parts of the world like the sub-Saharan Africa [2,3].

The prospects of all these changes taking place rapidly and not in distant furure is somewhat frightening. Mankind has never faced such rapid changes in its environment in the past. Social, economic and political upheaval is a distinct possibility. It may even be possible that we may already have started experiencing the greenhouse changes unknowingly Dr. Hensen, a meteorologist of the Goddard Space Centre, has in a congressional testimony attributed last year's serious drought in the USA to climatic changes brought out by the greenhouse effects [5].

Since oceans will also warm up with the warming of the atmosphere, there will be expansion of the sea water and consequent submergence of vast coastal plains. Scientists calculate that the sea level will rise between 20cm to 140cm if the average temperature increases by between 1.5 to 4.5°C; a temperature rise in the middle of this range would increase the sea level by about 80cm [2 3]. Nearly one-third of the mankind lives within 60km of the coastline. It can be well-imagined how the increase of sea level will affect habitation patterns in the world Fortunately, the rise of sea level, if it takes place, will be very slow and may take a century or two to occur, because warming of sea water is a very slow process. There may be enough time to adjust to the change.

If the apprehended depletion of the ozone layer really takes place, earth's surface will be exposed to much greater dose of ultraviolet radiation. There will be serious health hazards like increased incidence of skin cancer, eye diseases etc. The body's immune system will be adversely affected. Higher exposure to ultraviolet light may result in lower crop and timber yields [3,4]. Figure 2 shows schematically the social effects of atmospheric changes due to ozone depletion and increased greenhouse gases in the atmosphere.

Conclusion

It can be seen from the foregoing discussions that atmospheric perturbation like the acid rain, greenhouse effect, ozone leak etc. are phenomena which are not confined to any geographical area. All countries in the world will be more or less affected by atmospheric changes irrespective of who is the real culprit. It can be said without any doubt that industrialised countries are to day the maximum contributors of all atmospheric pollutants including greenhouse gases. The losers will be the poor non industrial nations. For example, if the sea-level really rises, small island states like Maldives will be completely wiped out for no fault of theirs. International understanding is therefore a pre-requisite for preparing ourselves to meet the challenges of global climatic changes by preventing them, to the extent possible and adapting to the changes that cannot be prevented, through co-operative action.

EFFECTS OF OZONE DEPLETION & GREENHOUSE EFFECT

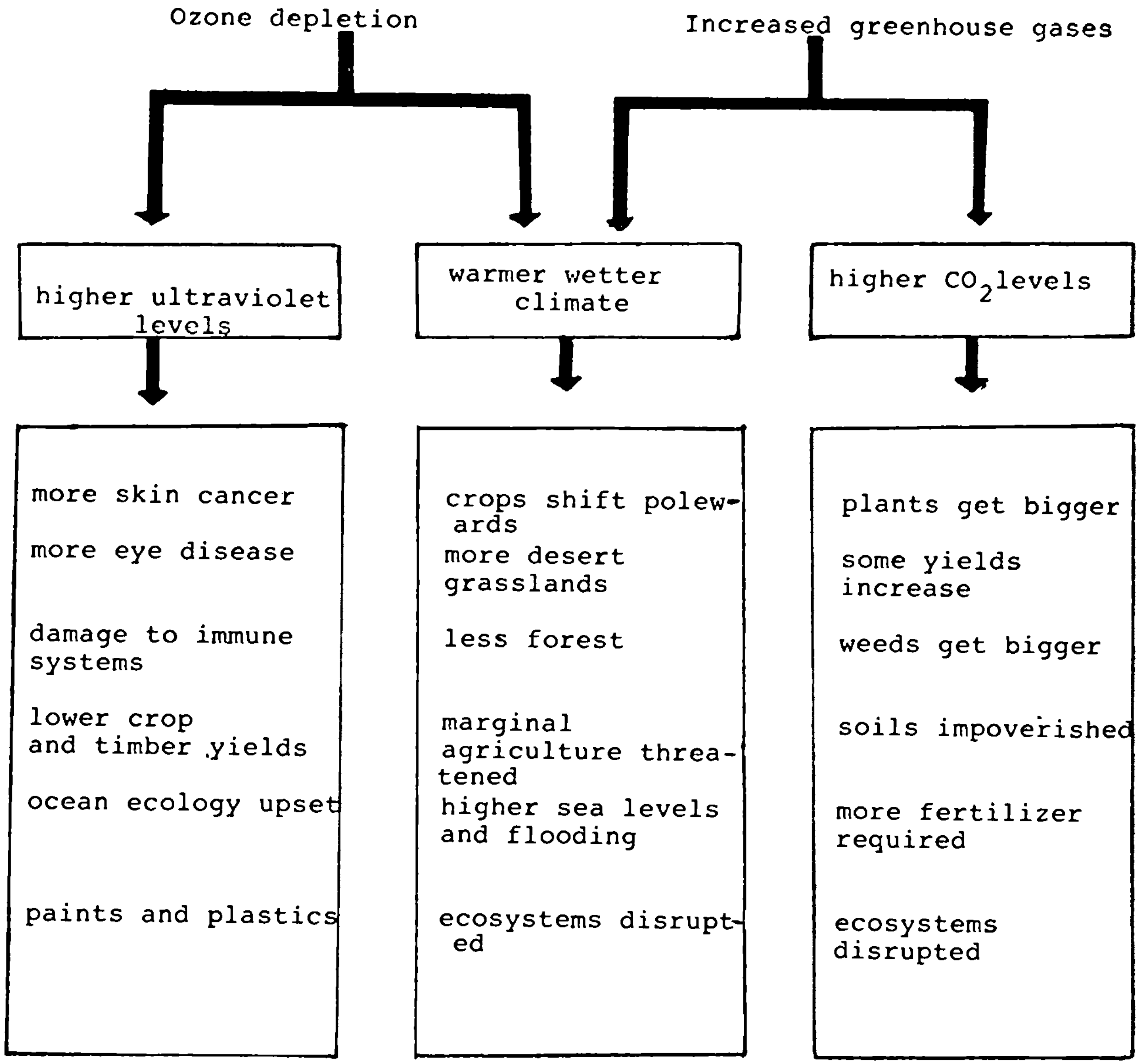

Fig 2 Social effects of atmospheric changes due to ozone depletion and increased greenhouse gases.

THE CHANGING RAINFALL–
A WARNING FOR FUTURE

Since serious climatic changes with far-reaching consequences are apprehended in near future, it has become imperative to keep a close watch over all our climatic parameters Rainfall is one of the most important climatic factors that controls the well-being of the people of a poor agricultural country like ours. Monsoon is as such somewhat unpredictable Any further perturbation can have really grave consequences. The changing rainfall pattern of Orissa within the last several decades has been researched very thoroughly by two scientists (Dr D. Lenka, Professor of Agronomy, Orissa University of Agriculture and Technology and Dr K. L. Pujari, Assistant Soil Conservation Officer, Bhubaneswar) besides many other organisations and institutions.

Both Dr Lenka and Dr Pujari [6, 7] have collected the overall rainfall data of Orissa and those of the individual districts over a long period from the beginning of the century to the mid eighties and analysed them in various ways to get a clear picture of the changing pattern It is not possible to make a detailed discussion of the analytical methods adopted by them in a report of this nature, but their broad conclusions will be presented.

ANNUAL VARIATION OF RAINFALL IN ORISSA

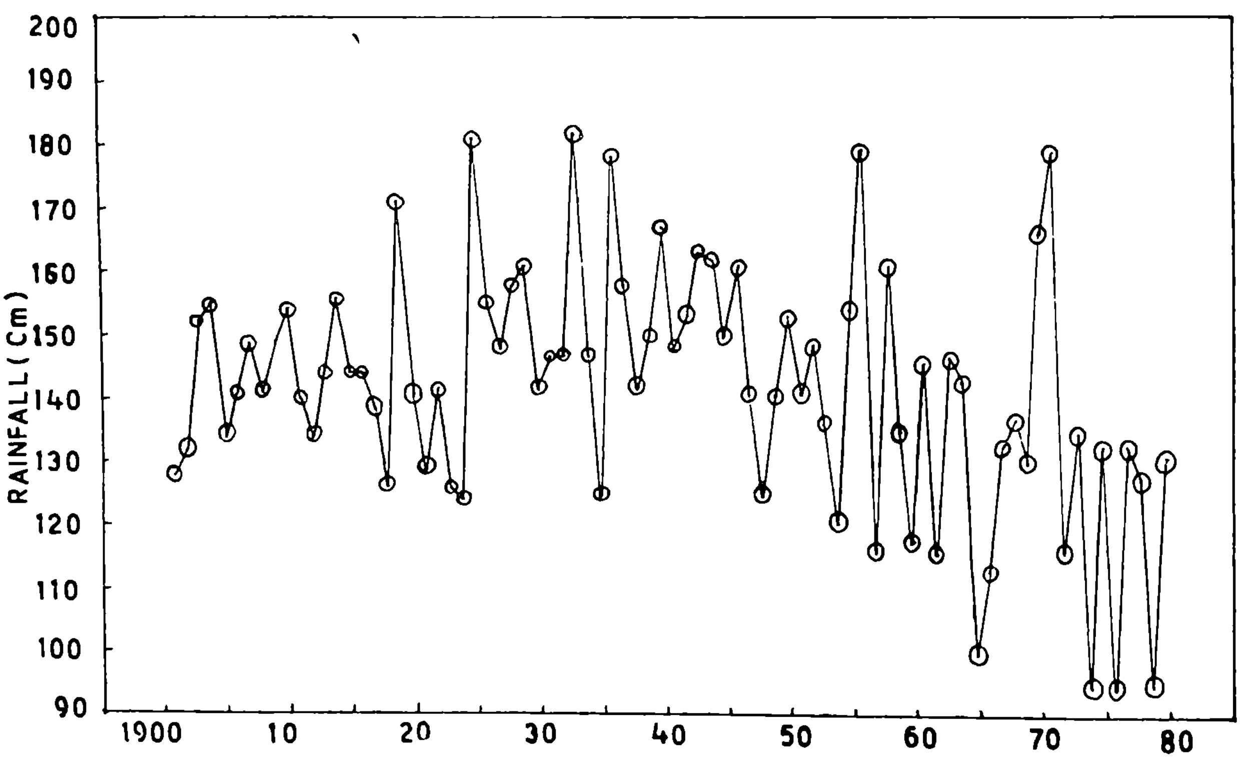

Fig 3 Variation of average annual rainfall of Orissa.

The average annual rainfall of Orissa between 1901 to 1985 is 139.4cm (standard deviation 18.6cm and coefficient of variation 13.27%). Individual data for every year are given in Table 2 and Fig 3. A close look at the rainfall data shows a small rising trend till about mid-fifties and after that, there is a decline in the rainfall which is particularly conspicuous after 1960's. The lower rainfall figures at the beginning of the century may not be very reliable because of paucity of data There were only a few stations where the rainfall data were collected for the Indian Meteorological Department Only after Independence, the number of data collecting centres were increased and the data acquisition system improved because of increased emphasis given to agricultural development. Table 3 gives the mean rainfall data alongwith the highest and the lowest recorded values for the different districts. The trends of rainfall variation for different districts are more or less similar to that for the state as a whole. Figure 4 shows the change of the rainfall pattern in five selected districts of Orissa.

Table 2

Mean Rainfall Data for Orissa from 1901 to 1985 [6]

Year	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915
Rainfall (cm)	128	132	152	155	134	141	149	141	149	154	140	134	154	156	144
Year	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
Rainfall (cm)	144	139	126	171	141	129	142	126	124	181	155	148	158	161	142
Year	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Rainfall (cm)	147	147	182	147	125	178	158	142	150	167	148	153	163	162	150
Year	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Rainfall (cm)	161	141	125	141	153	141	149	136	121	154	179	116	161	135	118
Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Rainfall (cm)	146	116	147	143	100	113	133	137	130	166	179	117	135	95	133
Year	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985					
Rainfall (cm)	95	133	128	95	131	118	118	137	130	161					

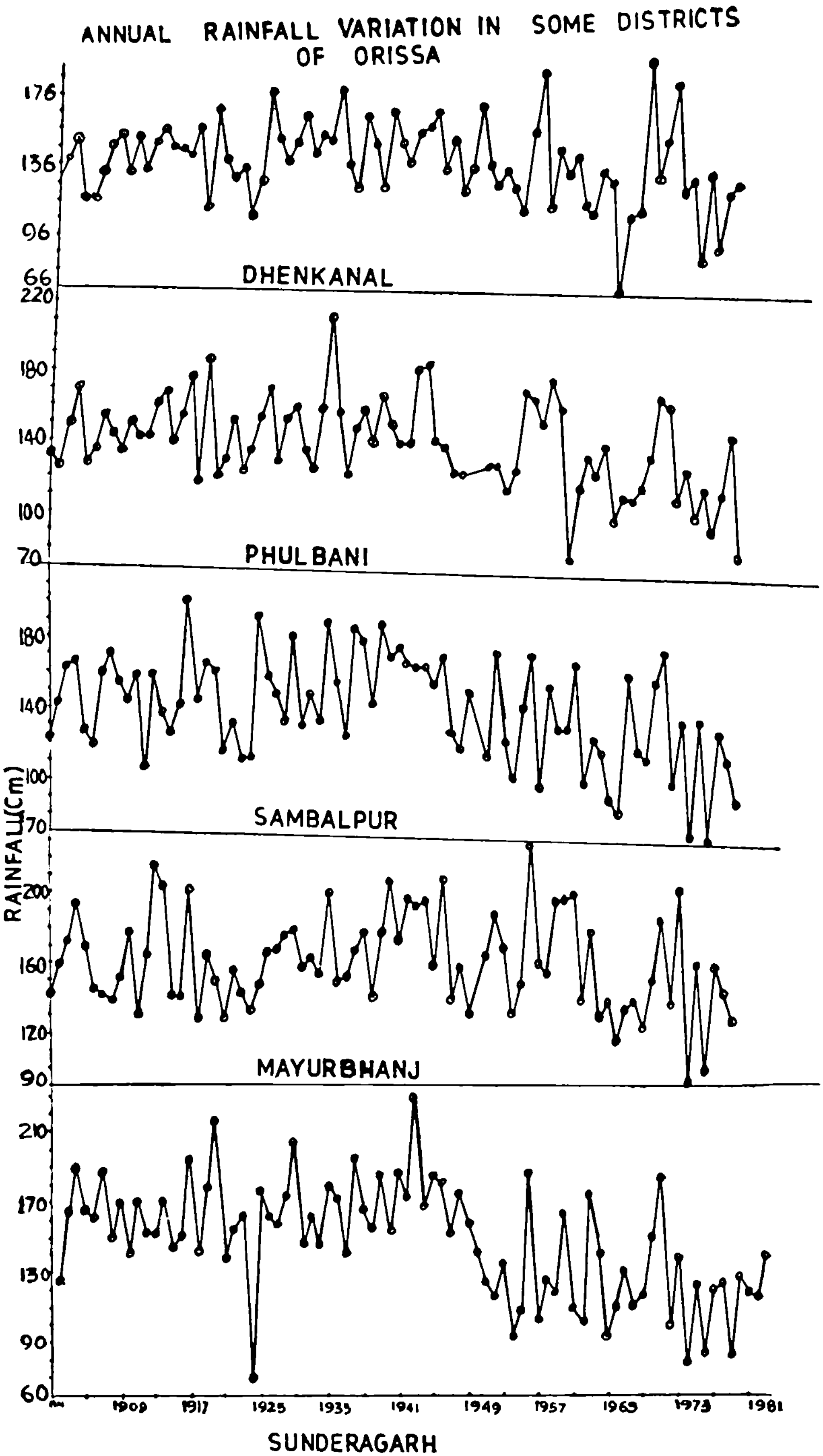

Fig 4 Variation of average annual rainfall of five selected districts of Orissa.

Table 3

Mean Rainfall of Different Districts of Orissa (1901 — 1985) [6]

District	No. of years	Mean Rain-fall (cm)	Std. Dev. (cm)	Coeff. varia-tion (%)	Maximum Rainfall (cm)	Minimum Rainfall (cm)
Mayurbhanj	84	159.5	27.0	16.9	227 (1956)	92.7 (1974)
					216 (1913)	100.4 (1976)
					208 (1946)	116.5 (1966)
Keonjhar	84	142.5	27.2	19.1	209 (1946)	85.2 (1976)
					235 (1961)	94.6 (1962)
					201 (1971)	96.6 (1954)
Sundergarh	82	147.9	32.5	21.9	228 (1943)	78.0 (1974)
					220 (1920)	69.7 (1924)
					201.7 (1929)	82.8 (1979)
Bolangir	83	131.9	27.6	20.9	191.4 (1917)	66.9 (1974)
					180.3 (1985)	78.9 (1965)
					178.6 (1925)	79.2 (1961)
Dhenkanal	85	137.8	23.7	17.2	199.3 (1968)	66.2 (1965)
					192.6 (1956)	81.8 (1979)
					182.9 (1925)	85.3 (1974)
Koraput	84	149.5	23.7	15.9	222.0 (1970)	92.3 (1965)
					195.6 (1914)	100.1 (1979)
					—	108.0 (1962 & 1974)
Phulbani	83	140.3	25.0	17.8	211.0 (1933)	81.3 (1979)
					187.0 (1919)	78.9 (1960)
					186.0 (1944)	—
Kalahandi	81	138.5	30.1	21.8	208.5 (1952)	66.9 (1965)
					200.5 (1961)	59.6 (1960)
					218.3 (1958)	73.9 (1979)
Cuttack	85	144.1	26.5	18.4	265.0 (1925)	95.1 (1960)
					209.0 (1936)	95.2 (1974)
					—	—
Sambalpur	84	141.3	27.6	19.5	201.0 (1917)	71.5 (1976)
					193.0 (1925)	73.6 (1974)
					190.0 (1933)	86.5 (1966)
Puri	85	139.7	24.0	17.2	200.1 (1936)	78.8 (1976)
					198.3 (1947)	95.1 (1965)
					—	—
Balasore	86	148.1	21.1	14.2	220.0 (1912)	93.1 (1959)
					219.0 (1940)	92.0 (1962)
					213.0 (1971)	—
					212.0 (1933)	—
Ganjam	85	128.1	22.3	17.4	192.7 (1919)	87.1 (1984)
					179.6 (1958)	89.6 (1976)
						78.0 (1966-67)
						77.5 (1966)

(Figures in the parentheses indicate the year of occurence)

Dr Lenka [6] analysed the data on the basis of decennial variation of rainfall in the different districts and in the state as a whole (Table 4, Fig 5 to 8). A perusal of the table and the figures clearly shows a decreasing trend of rainfall in varying degrees since the fifties.

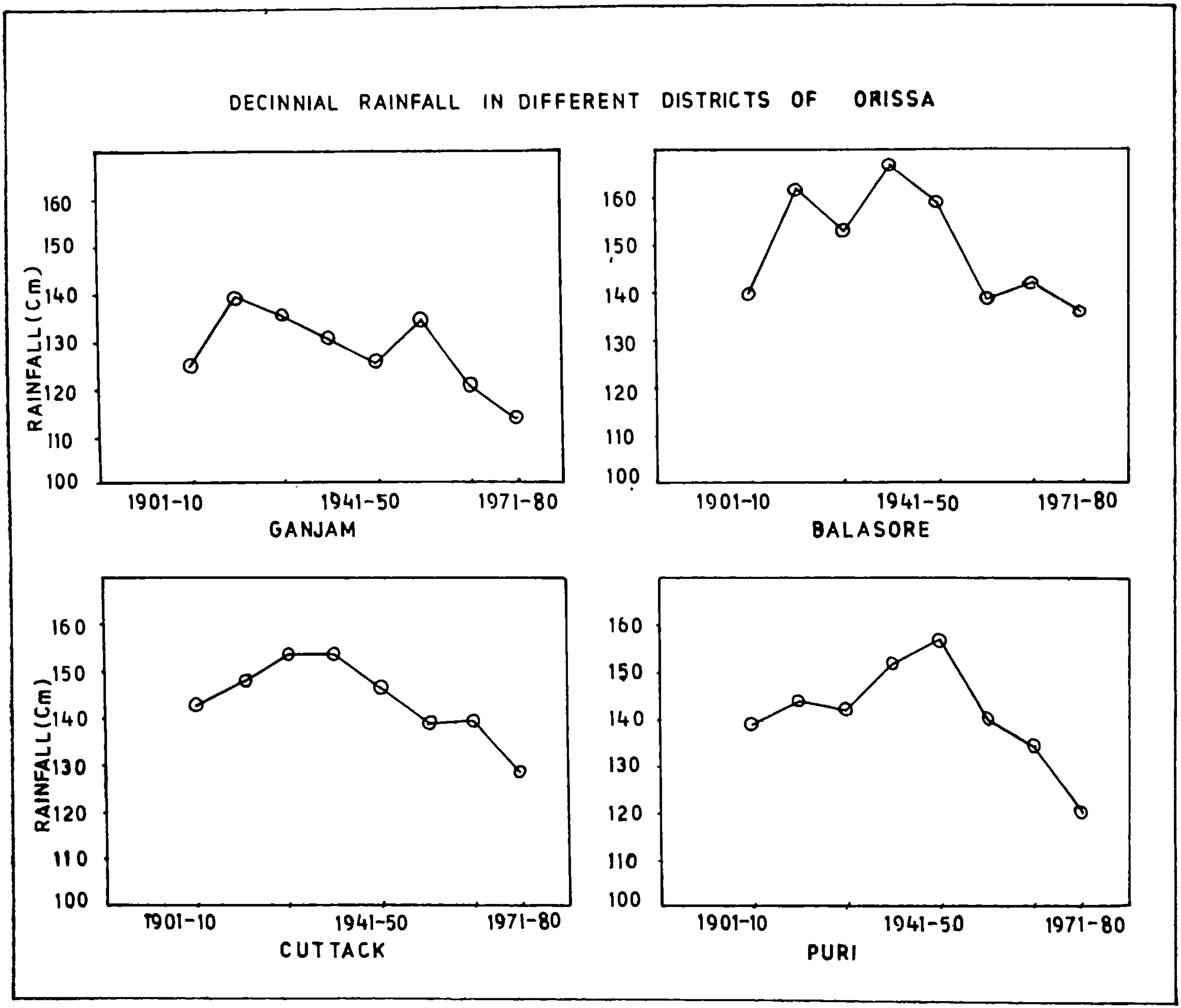

Fig 5 Decennial rainfall in some districts of Orissa.

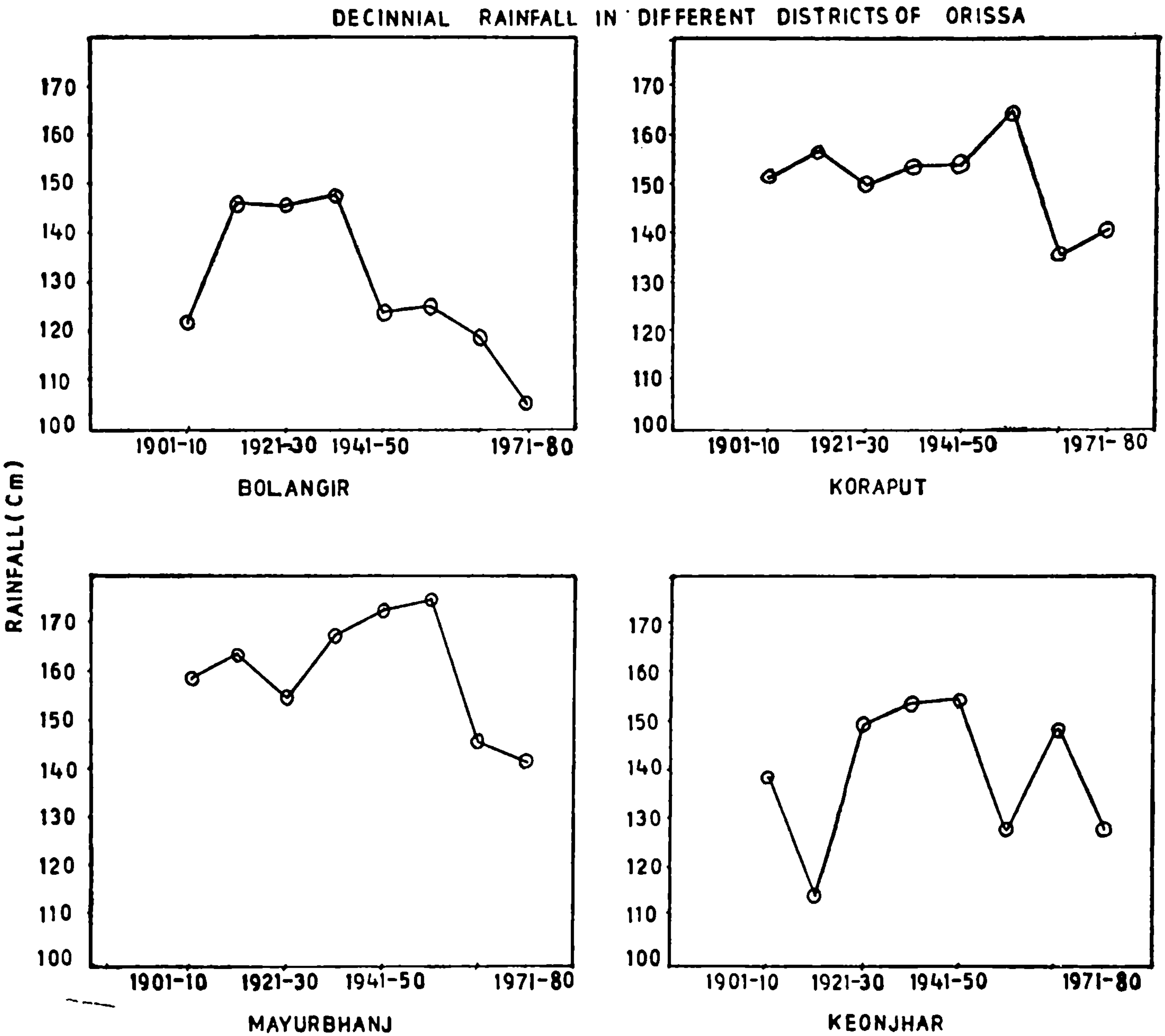

Fig 6 Decennial rainfall in some districts of Orissa.

DECINNIAL RAINFALL IN DIFFERENT DISTRICTS OF ORISSA

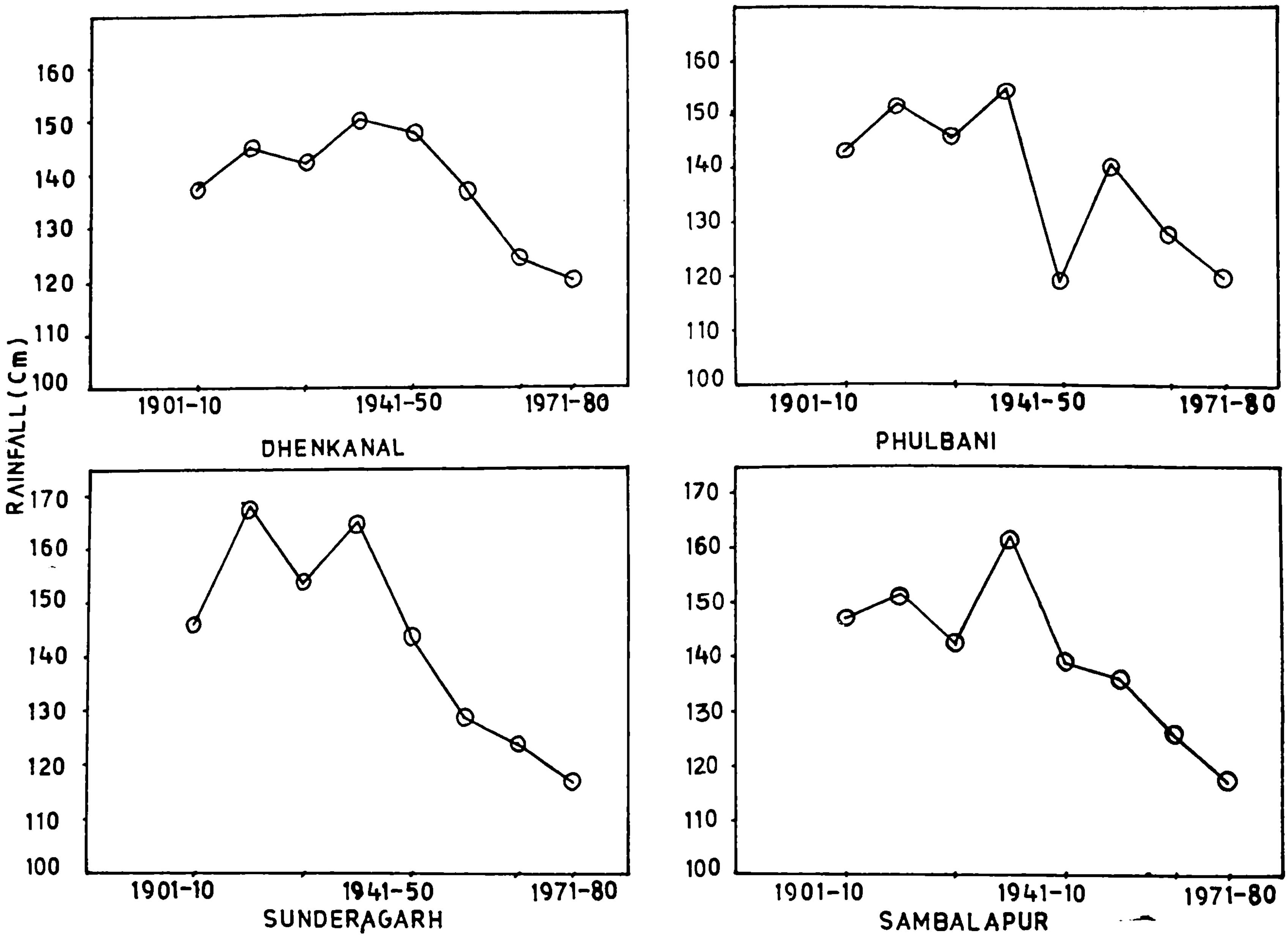

Fig 7 Decennial rainfall in some districts of Orissa.

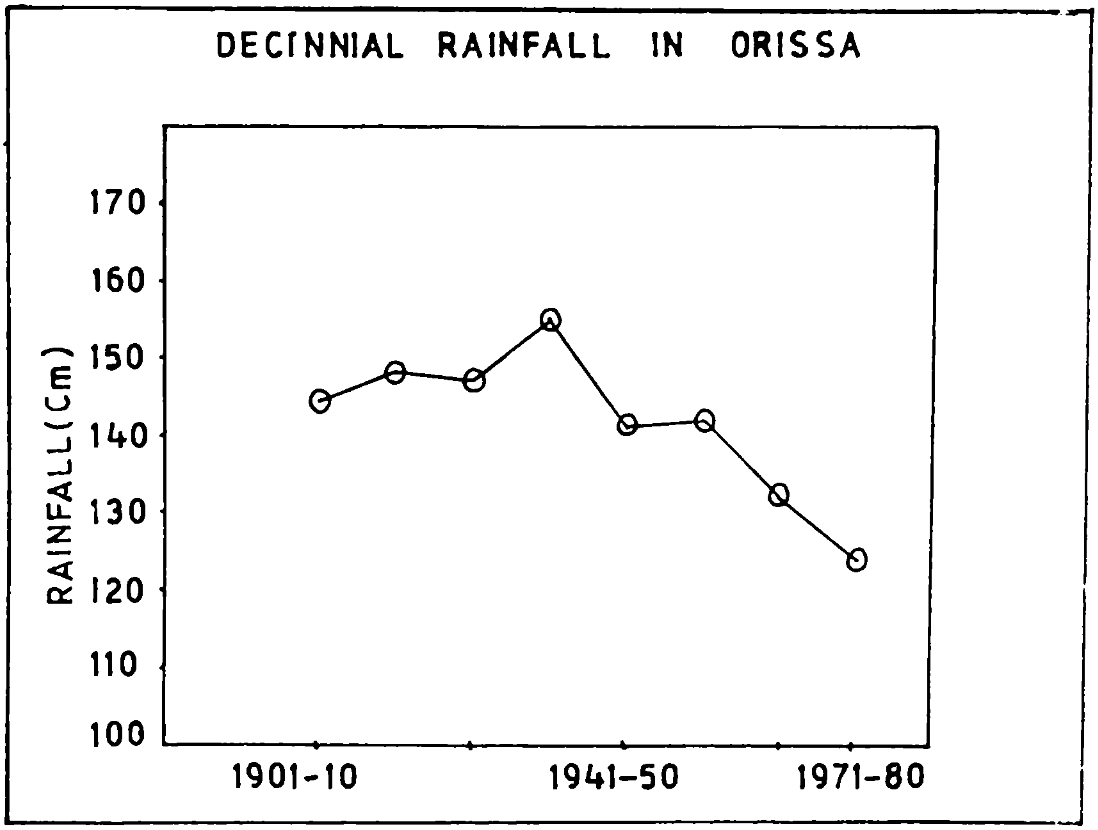

Fig 8 Decennial rainfall of Orissa

Table 4

Decennial Variation of Rainfall in Districts of Orissa (cm) [6]

Particulars	1901-10	1911-20	1921-30	1931-40	1941-50	1951 60	1961-70	1971-80	1981-85	1901-85
Northern Plateau										
Mayurbhanj	159	164	155	168	173	175	146	142	147	159
Keonjhar	139	114	150	154	155	128	149	128	159	142
Sundergarh	146	168	154	165	144	129	124	117	132	156
Mean	148	149	153	162	157	144	140	129	—	153
Central Table Land										
Sambalpur	147	151	143	162	139	136	126	117	129	141
Dhenkanal	137	145	142	150	148	137	124	120	133	138
Bolangir	122	146	146	148	124	125	119	105	117	132
Mean	135	147	144	153	137	133	123	114	—	137
Easternghat Zone										
Koraput	152	157	150	154	154	165	136	141	135	149
Kalahandi	144	138	133	136	135	157	143	144	130	138
Phulbani	143	152	146	155	119	141	128	120	135	140
Mean	146	149	143	148	136	154	136	128	—	143
Coastal Zone										
Cuttack	143	148	154	154	147	139	140	129	135	144
Puri	139	144	142	152	157	140	134	120	118	140
Balasore	140	162	153	167	159	139	142	136	136	148
Ganjam	125	140	136	131	126	135	121	114	116	128
Mean	136	148	146	151	147	138	134	125	—	140
Stage Mean	144	148	147	155	141	142	132	124	132	143

Dr. Pujari's analysis of the rainfall data from 1901 to 1986 was somewhat different [7]. He took the arithmetic mean of the highest and the lowest recorded values over the entire period of study as the median rainfall value for the period. All those years having rainfall within ± 10 cm of the value were considered as years of normal rainfall. Decreased or increased rainfall years were those when the rainfalls were below or above the above range respectively. Decreased rainfall years were regarded as years of meteorological drought. Depending on the frequency of occurence of drought and excess rainfall, he divided the entire period of study into four sections, viz, 1901-57, 1958-71, 1972-81, 1982-86. In the first section of 57 years, the rainfall was more or less on the increased side with only about 9% of years having drought condition. In the second phase of 14 years, the whole state started experiencing increased frequency of droughts (app 30%). In the third phase, almost 50% of the years had drought conditions (Table 5).

Thus, it is found that in whatever way we may analyse the rainfall data, the inescapable conclusion is that there was a steady or a slightly increasing trend of rainfall from the begining of the century to the middle of fifties in almost all the districts; thereafter there was a decreasing tendency with fluctuations becoming more pronounced in the seventies and eighties. Our developmental activities started in the fifties which picked up momentum in the seventies and eighties.

Dr. Pujari also examined the number of rainy days per year in different districts in the post-Independence period and observed a decreasing trend and erratic behaviour in all the districts. This is not congenial for agriculture or any other useful purpose. He arranged all the districts of the state into the following seven groups in the order of decreasing rainy days : Mayurbhanj> (Balasore, Puri, Keonjhar) > Phulbani > (Cuttack, Ganjam, Dhenkanal)> Koraput> (Sundergarh, Sambalpur)> (Bolangir, Kalahandi). Thus, Bolangir and Kalahandi districts have the minimum rainy days in a year or the maximum erratic rainfall. Rainfall is the least erratic in Mayurbhanj. Figure 9 shows the number of rainy days per year over a last few years in ten selected districts.

Table 5

Years with Increased, Decreased and Normal Rainfalls [7]

District	1901 — 1957			1958 — 1971			1972 — 1981			1982 — onwards		
	I	D	N	I	D	N	I	D	N	I	D	N
Sambalpur	26	15	16	5	7	2	—	6	4	—	1	3
Kalahandi	18	17	22	6	4	4	—	7	3	1	2	1
Koraput	17	6	34	5	7	2	1	5	3	—	2	2
Sundergarh	34	7	16	3	8	3	—	7	3	1	1	2
Bolangir	21	19	17	4	8	2	1	8	1	1	2	—
Ganjam	17	12	28	5	5	4	—	7	3	—	2	2
Cuttack	16	10	31	3	6	5	—	6	4	1	1	2
Mayurbhanj	26	14	17	3	9	2	1	6	3	1	1	2
Keonjhar	20	17	20	4	3	7	—	6	4	3	—	1
Dhenkanal	16	13	28	3	6	5	—	8	2	1	2	1
Phulbani	25	9	23	4	7	3	—	6	4	1	1	2
Balasore	17	15	25	4	6	4	—	7	3	1	2	1
Puri	20	13	24	4	4	6	—	7	3	—	3	1
Orissa (whole)	41	6	10	6	4	4	—	5	5	1	2	1

I—Increased rainfall, D—Decreased rainfall, N—Normal rainfall

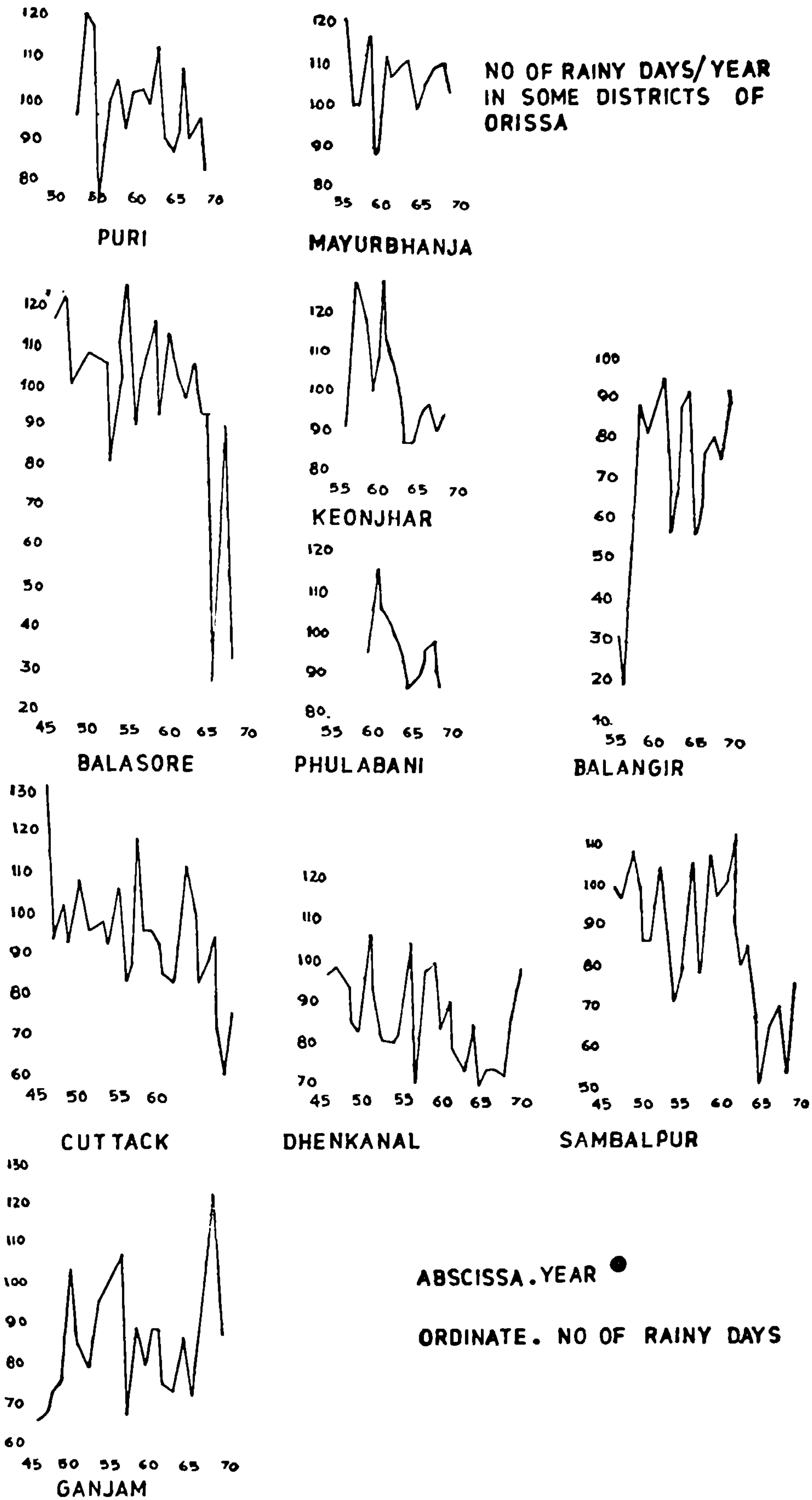

Fig 9 Number of rainy days per year in ten selected districts of Orissa.

Two scientists of the Sambalpur University, Shri A. B. Mishra and Dr. M. C. Dash, have made a detailed study of the climatic changes in the Sambalpur and Jharsuguda region around the Hirakud reservoir. They have also reported a decreasing tendency of rainfall and the number of rainy days in a year since the fifties. Besides, they found decreasing trends in the morning humidity but increasing trends in minimum and maximum temperature, evening relative humidity and atmospheric pressure [*8*].

The above findings are no doubt disturbing. The reasons can very well be speculated. It may not be entirely due to global climatic change brought about by the greenhouse effect. The influence of greenhouse gases on global climate was not noticable till the seventies. If at all, it might have begun to be felt in the eighties but is most likely to become the most important controlling factor of climatic change in all parts of the world in near future.

It is established by now with a fair degree of certainty that loss of vegetative cover adversely affects rainfall in a locality. In the absence of vegetation, the soil becomes bare and desiccated by the hot sun in tropical climates. Consequently, the nature of aerodynamics of air changes and convection currents help in moving the precipitating clouds to farther places. The dust menace increases and the behaviour of precipitation changes— sometimes with the decrease of number of rainy days [*9*].

It is naturally tempting to correlate the decreasing rainfall, as well as, its greater irregularity in the past few decades to the loss of forest cover. According to some estimates, about 80% of India was covered by forests around 3000 BC [*10*]. Waves of migrants coming to India — many from desert and semi-desert lands — changed the face of the Indian landscape. Pressure on our forests started being felt from the Moghul period when agriculture lands were created from forest lands. The same continued in the British period when, in addition to the above, commercial exploitation of forests started for laying railway lines, manufacture of paper and other industrial products. The situation became alarming only in the post-Independence period when large irrigation projects, industrial ventures and other developmental activities were taken up at the cost of forests. Forests were also considered as an important source of revenue for such developmental activities. This encouraged large scale felling of trees — both legal and illegal. Serious attempts for forest conservation and regeneration have started only recently. Reliable statistics on the forest cover in the pre-Independence and the early part of the post-independence periods are not available. Those available with the forest departments are often misleading Lands without even a blade of grass are sometimes recorded as forests in official files True picture about forest cover emerged only after remote sensing techniques developed. According to the National Remote Sensing Agency (NRSA) report of 1984, the total forest area of Orissa in 1972-75 was about 48,383sqkm, which is reduced to 39,425sqkm in 1980-82. Thus a total 8,958 sqkm of forest area was lost during the period which constituted about 5 75% of the total geographical area of the state [*11*] At the national level, the loss of forest area in terms of the percentage of the total area of the country during the period was about 2.69. It is therefore likely that such rapid loss of vegetative cover has caused the change of the rainfall pattern, particularly after the seventies In such a situation, reports of frequent droughts in some districts like Kalahandi in recent years is not difficult to understand

It should be pointed out here that one cannot be cent percent certain in ascribing the change of rainfall pattern only to the depletion of forest area The behaviour of monsoon is very complex and has not been clearly understood. Environmental conditions in far off places like the temperature of the ocean current along the coast of Peru in South America (El Nino current) and

the difference of atmospheric pressure over the Pacific ocean near Tahiti in French Polynesia and the Indian ocean near Darwin in northern Australia (Southern Oscillation) are said to influence the course and intensity of monsoon wind in India [*12*]. Meteorologists have even found some similarity between the Indian summer monsoon and the rainfall fluctuations over the Sahel region of northern Africa. In both the places, there has been a gradual decrease of rainfall from 1960 onwards [*12*]

Thus, though the behaviour of monsoon wind greatly depends on the global conditions, it can also be influenced by local conditions. The foregoing discussions in this section clearly show that there exists a good correspondence between the decline of precipitation and the decrease of forest area in Orissa to yield a statistically significant correlation and further, it is quite well-known that forest loss does adversely affect the microclimate of an area.

Conclusion

We have already started experiencing perceptible climatic change in the form of decreased and irregular rainfall since the last few decades. This has been ascribed by many to the loss of forest cover. If the deforestation process continues further, it may approach a low plateau limit and thereafter, there should not be any more change of rainfall pattern, if the hypothesis is correct. And further, if the afforestation programmes successfully come through, the trend should, in principle, be reversed. This unfortunately may not be so. The global factors like the greenhouse effect already discussed earlier, may completely predominate over the local factors in influencing the climatic change. Therefore, if anything, ***the change of climate may take place at a faster rate in the coming decades.*** But how and in what manner the change will take place is difficult to predict accurately at this stage Nevertheless some attempts can be made towards reasonable forecasts over a few decades as already discussed in earlier part of this report.

It will be wise to prepare ourselves for the change in a disciplined manner. The political leaders, administrators, planners and media should take note of it. While panic and pessimism will not help, it is no more than common sense to equip ourselves with the necessary tools, scientific and administrative, as also with the required motivation, to integrate and modulate the changes, if and when they come about.

THE INCREASING CONCERN OF POLLUTION

Air pollution is a subject of great concern in the present world because of growing industrial activities and increasing combustion of fossil fuels. It is becoming increasingly clear that sources and causes of air pollution are more diffuse, complex and interrelated and the effects are more widespread, cumulative and chronic than hitherto believed Pollution problems were once considered local ones, but these have now attained regional and even global proportions.

Permissible Limits of Pollutants in the Environment

As per the definition of the World Health Organisation (WHO). air pollution is a "*situation in which the out-door atmosphere contains materials in concentrations which are harmful to people or their environment*" [*13*]. It is therefore necessary to know to what extent a pollutant present in an atmosphere can result in a situation

in which the latter can be termed as "polluted"? This is a difficult problem because many of the adverse effects of pollutants in the environment are not direct and immediate but cumulative. Moreover, some of these effects, e. g., photochemical smog formation, also depend on the meteorological conditions. Nevertheless concentration limits of some primary pollutants have been laid down beyond which an ambient air can be considered polluted in a legal sense (Table 6).

Table 6

Ambient Air Quality Standards in India

(Concentration limits in microgram/cubic metre)

Area Category	Suspended Particulate Matter (SPM)	Sulphur dioxide	Oxides of Nitrogen (Knox)	Carbon monoxide
Industrial and Mixed Use	500	120	120	5000
Residential and Rural	200	80	80	2000
Sensitive	100	30	30	1000

The standards for different category of areas are different Obviously one expects a cleaner and more tranquil atmosphere at home than in the work place. Hence standards for residential areas are stricter than for industrial areas. Eco-sensitive areas like tourist resorts, places with archeaological monuments, game sanctuaries etc. need special protection for which pollutant levels in the atmosphere need to be very strictly controlled. One conspicuous absence in the standards laid down is the market place. These should be categorised separately. Indian bazars are notoriously dusty and noisy. If residential area standards are expected in market places, the expectation is no doubt very unrealistic. Standards for industrial areas are obviously too lax to apply to market areas. Since standards have legal implications, it is necessary that separate standards for market/commercial areas should be laid down.

The standards mentioned in table 6 relate to the "open" or "general" environment which is different from the "work environment". An industrial worker is exposed to a much greater dose of a specific pollutant in the air which will be much higher than what can be permitted in the general outside environment. For example, a worker in a sulphuric acid plant is exposed to a much greater concentration of sulphur dioxide than the ambient air standard for the gas given in Table 6. For work environment, the permitted limits of toxic substances are expressed by the "*thresh-hold limit values* (TLV's)". The TLV is defined as "*the average concentration of the substance in ambient air for a normal eight hour work-day or forty hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects*" [*14*]. The TLV values of some common pollutants of work environment are given in Table 7.

Table 7

TLV Values of Some Common Pollutants [15]

Substance	Sulphuric acid	Sulphur dioxide	Ammonia	Nitrogen dioxide	Carbon monoxide	Chlorine
TLV value	1	5	18	6	55	3
Substance	Hydrogen fluoride	Coaltar pitch volatile		Methanol	Benzene	Asbestos dust
TLV value	2.5	0.2		260	10	2

(Values are in milligram/cubic metre except for asbestos dusts which is in number of fibres/cubic centimetre)

Air Quality of Some Industrial Areas in Orissa

The two main centres of industrialisation in Orissa are the Rourkela-Rajgangpur areas and the Angul-Talcher area. In these areas are situated many large air-polluting industries, viz, Rourkela Steel Plant (RSP) (including its fertiliser plant), Rourkela, Crissa Cement Ltd. (OCL), Rajgangpur, Talcher Thermal Power Station (TTPS), Talcher, Fertiliser Corporation of India (FCI), Talcher, National Aluminium Co. (NALCO) (Smelter Unit), Angul and National Aluminium Co. (NALCO) (Captive Power Plant), Angul. In addition to these, there are many ancilliary and downstream industries in the medium and small scale sectors. The cumulative effect of all these industries, as well as, other human activities have resulted in a great deal of air pollution in the areas making the lives of inhabitants uncomfortable.

In the Angul-Talcher area, the main pollutant is suspended particulate matter (SPM) arising out of two thermal power stations (NALCO, 480 MW and TTPS, 470 MW) and the coal based fertiliser plant belonging to the FCI. The following gives the list of stacks through which emissions are released and their heights. Height of the stacks helps in greater dispersion of the pollutants.

Table 8

Main Stacks of Angul-Talcher Area

Plant	No. of Stacks	Height (in metres)
FCI · Steam Generation Plant)	1	80
TTPS Stage I	2	60 each
TTPS Stage II	1	125
NALCO, CPP	3	150
NALCO, Smelter (Fume Treatment Plant)	4	50 each

The State Pollution Control Board has been regularly monitoring the ambient air quality of the Angul-Talcher area since more than a year in the TTPS colony and the NALCO township. The monitoring is done daily on a 24 hour basis with eight hours average. Figure 10 shows the monthly average values of the suspended particulate matters at the two stations for the year 1987-88. A perusal of the figure clearly shows that the ambient air in the NALCO township at Angul is much cleaner or rather less palluted, than that in the TTPS colony. While, in the former area, the SPM in air remains within the limit prescribed for residential areas (200 micrograms/cu metre vide Table 6) for most part of the year, the same is present in the air of the TTPS colony in concentrations much above the limit. In the winter months, the concentration of SPM even goes beyond three times the prescribed limit ! The SPM level at both the stations remains more or less within the prescribed limit during the monsoon months. This is expected because of the wash out of pollutants in the air by rain. In cold winter months, there is less mixing and dispersion of pollutants in air because of atmospheric conditions (temperature inversion etc). This results in higher concentration of pollutants in the atmosphere as can be seen in the figure *[16]*.

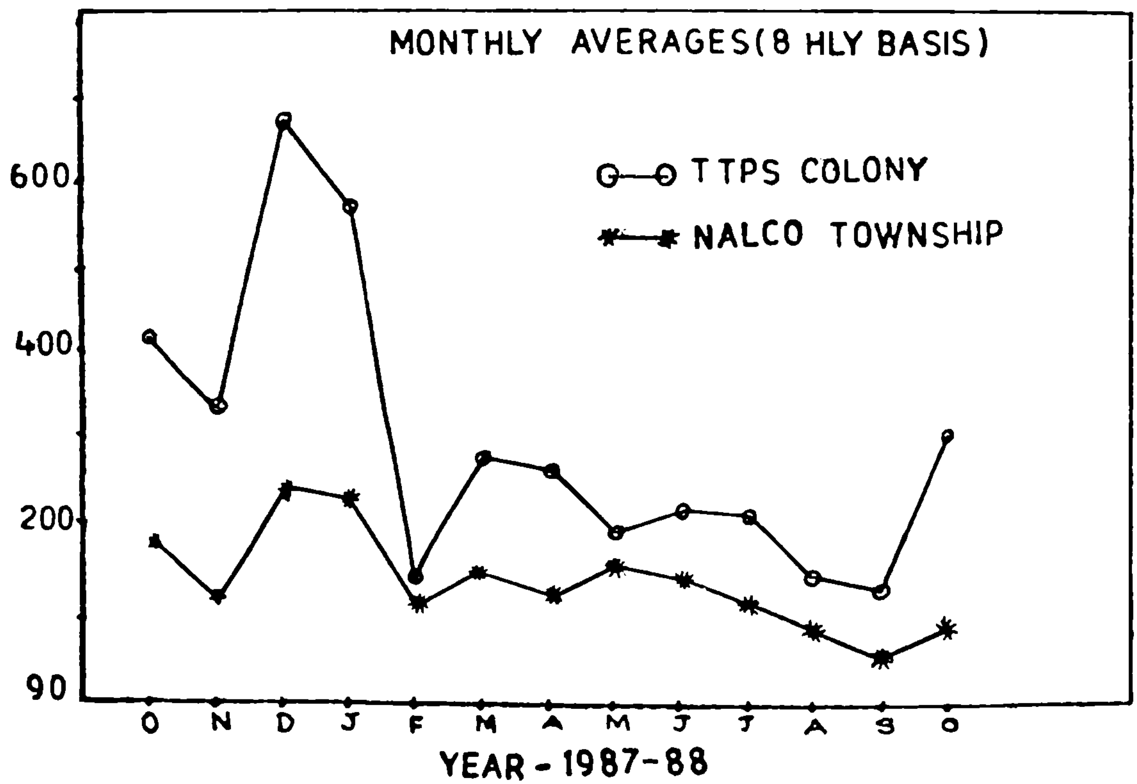

Fig 10 Monthly average values of SPM in Angul-Talcher area

The particulate matter obviously comes from the extensive use of coal by the power plants and the fertiliser plant; the contribution of the latter is definitely less Indian coal generally has high silica (ash) content but the sulphur content is less with the exception of coal from Assam. The ash content of coal is sometimes as high as 35-40%. The average daily coal consumption of TTPS and NALCO power plants is about 13,000MT. Assuming even a low figure of 30 for the percentage of ash in coal, one can calculate that 3,900MT of ash is generated daily out of which generally 80% go through the stacks as flyash and the rest collected as bottom ash. One can therefore easily imagine the flyash nuisance in the area if it is not arrested from the boiler stacks by appropriate control arrangements like elctrostatic precipitator (ESP). The boilers of the NALCO power plant have ESP's claimed to be of 99.6% efficiency The two boilers of the TTPS Stage II have ESP's but all the four boilers of the Stage-I plant had no ESP till recently. Very recently, however, one of them has been fitted with one ESP and installation of the same in other boilers is in progress. It is to be seen when the installations will be complete and how the precipitators work after their installation. Thermal plants belonging to the electricity boards all over the country, with a few exceptions, are not known for their efficiency in proper operation and maintenance of plants and machinery. Even in the capital city of New Delhi, a thermal power plant could very successfully instal a proper ESP only a few months back after a lot of public criticisms, parliament questions and pressure by the Central Pollution Control Board and the Government of India in the Ministry of Environment.

The sulphur dioxide and Knox (oxides of nitrogen) levels in the ambient atmosphere of Angul-Talcher area have not been measured as regularly as that of the particulate matter. A few measurements in the year 1988 show that the concentrations of sulphur dioxide and the oxides of nitrogen to be in the range 7.8-22.9 and 4.2-9.0 microgram/cu. metre respectively at Talcher (TTPS Colony) and 6.4—10.7 and 3.4 — 6.7 microgram/cu metre respectively at Angul (NALCO township). Thus, the pollution due to the above gases does not appear to be as serious as that due to flyash. A more clear picture will emerge when more data over a long period is collected. Low sulphur content of the coal used in the thermal plants may be the reason for the comparatively less emission of sulphur dioxide. This should not give us a sense of complacency. The situation may change when the proposed super thermal power plant comes up near Talcher.

There have been in the past many public complaints of health hazard in Talcher area caused by the air borne flyash. No systematic study has been done to verify them. A one-time health survey of the children of a primary school near the TTPS made by a voluntary agency revealed that more than 80% of children suffer from various types of minor and major respiratory ailments. The survey appeared to have been made in the winter season of 1986-87. It was preliminary in nature and the doctors admitted to its inadequacy due to the lack of facilities for more detailed and confirmatory tests. The findings of the voluntary agency have been contested by the Chief Medical Officer of the district. A health survey was made by his team of experts in the month of July, 1987 and according to their finding, only a negligible fraction of the children examined suffered from respiratory problems. The apparent disparity in the two findings becomes clear on a close scrutiny. The pollution level in the atmosphere invariably remains high during winter months due to stable atmospheric conditions and sometimes there are epidemics of cough, cold and other respiratory diseases. Since the examination by the voluntary agency was done in the winter season, it could be that at the very point of time there was an epidemic. As against this, the survey of the district medical authorities was done during rainy season when the atmosphere remains fairly

clean due to wash out by rain The true and normal situation may be somewhere in between the two extreme findings. A lesson to learn from this is that any grab sampling of this type may lead to misleading conclusions A large sample size based on observations made over a large area and a long period of time is a pre-requisite for obtaining truthful results.

The steel city of Rourkela is the second largest town of Orissa A large integrated steel plant, the Rourkela Steel Plant (RSP) alongwith its associated fertiliser plant is situated in this town. The other large industries in the area are; The Indian Detonators Ltd. (IDL) formulating explosives, the Orissa Industries Ltd. (ORIND) manufacturing ceramic products and the Otto India Ltd. (OIL)—an engineering industry. The air pollution potential of the last unit is marginal. The pollution of the ORIND is mainly by fugitive dust mostly confined to the work environment. The IDL is normally not an air polluting industry but air pollution occurs during blasting operations (dust and oxides of nitrogen). Thus, the main source of air pollution in Rourkela area is from the RSP and its fertiliser unit (nitrogenous fertilizer-calcium ammonium nitrate).

In addition to the above large scale industries, the Rourkela area has three medium scale industries and over 1500 other industries belonging to the small scale and the tiny sectors. Their contribution, as well as, that of the vehicular traffic towards the air pollution of Rourkela are difficult to estimate, but will certainly be not more than the pollution caused by the steel and the fertiliser plants.

The RSP is a large integrated steel plant with a production capacity of about 93,000MT and 97,000MT respectively of ingot iron and saleable steel per month. It has many units and in total about 60 number of various types of small and large stacks. Almost all the units of the RSP are potential sources of air pollution. The major air pollutants are sulphur dioxide, acid mist, oxides of nitrogen, carbon monoxide, hydrocarbons, ammonia, hydrogen sulphide and suspended particulate matter (consisting of ore dust, flyash and other particles). A flow chart of the RSP alongwith various sources and types of air pollution is given in Fig. 11.

There was no awareness or culture of pollution control at the time when the RSP was constructed. The same culture or rather non-culture - continued till recently. The old inertia has not yet been fully shaken off. The amounts of different pollutants released through the stacks of the different units, as per the reports of the authorities of the RSP themselves, are given in Table 9. It is very clear from the table that a good amount of pollutants are released into the atmosphere by the industry [17] and, as it stands to day, is a big polluting industry.

FLOW CHART WITH AIR POLLUTANTS OF ROURKELA STEEL PLANT

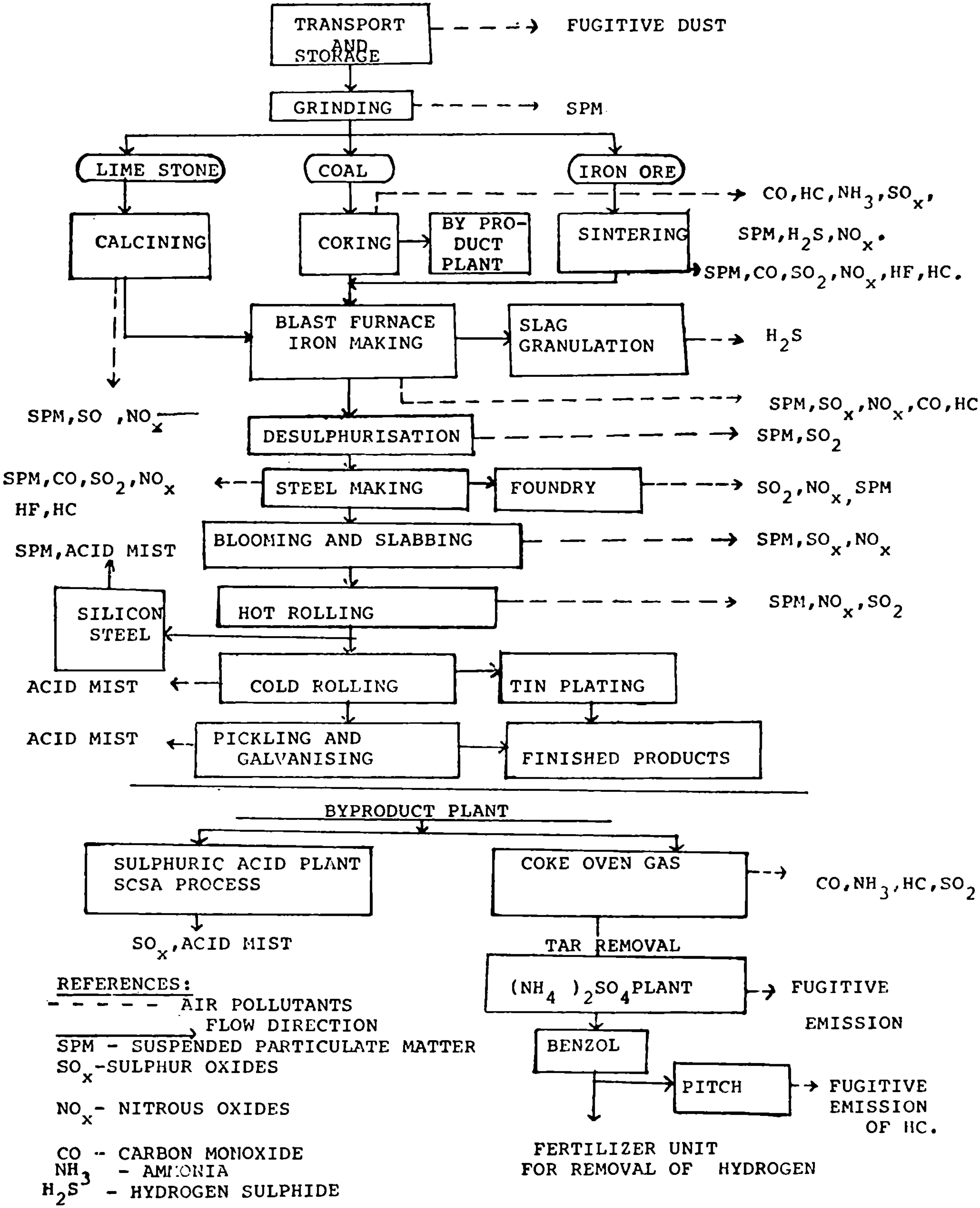

Fig 11 Various sources of air pollution in the RSP.

Table 9

Average Stack Emission Data of the RSP [17]

(All figures are in kg/hr except the acid mist)

Sl No.	Unit	No. of Stacks	SPM	Sulphur dioxide	Knox	Carbon monoxide	Hydrocarbon	Acid mist (mg/Nm³)
1.	Sintering plant process waste gas	8	156	0.7	0.7	4 79	30	—
2.	Steel melting shop-open hearth	4	40.6	0.13	0.07	644	3.9	—
3.	Thermal plant CPP I	1	615	0.94	0.32	743	3	—
	CPP II (only one in operation)	2	255	3.2	1 0	2.215	6	—
4.	Foundry (sand plant)	2	51	0.63	0.004	—	—	—
5.	Calcining plant (Rotary kiln)	1	5.1	0.004	0.005	68.5	65	
6.	Sulphuric acid plant	1	—	372.58	—	—	—	5494 47
7.	Coke oven (Battery No. 4)	5	8.4	0.6	0 05	732	76	—
8.	Blast furnace	4	16.98	0.36	—	—	—	—
	Total		1148.1	379.14	2 149	2194.5	183.9	5494 47

The ambient air quality of Rourkela area in and around the steel plant has been monitored at four locations by two agencies, namely M/s. R. V. Brigg Pvt. Ltd. and M/s. Superintendence Ltd., in two different months of 1937 (April and September). Six observations were taken in each month. The results are given in Table 10.

Table 10

Ambient Air Quality in Rourkela Area [*17*]

(All data in microgram/cubic metre)

Location	April, 1987			September, 1987		
	SPM	Sulphur dioxide	Oxides of Nitrogen	SPM	Sulphur dioxide	Oxides of Nitrogen
Modernisation building	278-354	64-104	7.8-49.8	45.5-216	35 5-47.2	17.5-35.0
Captive power Plant-II	179-370	160-180	3.7-49	21.5-134.3	19 5-24.8	6.9-18.7
Railway station	391-822	56-92	20.9-106	79.1-120.4	20.6-30.6	13.8-32.7
Fertiliser ** township		Not done		95-240	25.0-27 0	

* Results are of 24 hours average with 8 hours reading

** No reading was taken in April, 1987. The values are monthly average values for the months of October, November & December, 1987.

As can be seen in Table 10, the air quality of Rourkela does not remain for most of the time within the limits prescribed for residential areas with respect to sulphur dioxide The same is also true for oxides of nitrogen in some locations. With regard to the suspended particulates, even standards prescribed for industrial areas are exceeded. The State Pollution Control Board has also measured a few samples of ambient air around April, 1987 and the results are similar to those given in Table 10. As expected, the air is cleaner in the month of September due to wash out by rain. Unfortunately, no systematic data is available for winter months when the pollution level in the air is expected to be high.

It is very surprising that in spite of high level of oxides of sulphur, acid rain has not been detected in the Rourkela area On the contrary, scientists of the Regional Engineering College, Rourkela have observed the rain water at Rourkela to be slightly on the alkaline side which they have ascribed to the dissolution of ore and cement dusts from the steel plant of Rourkela and cement plants of Rajgangpur respectively in the rain water [*18*]. This anomalous observation should be checked up further for confirmation. It may be mentioned here that acid rain does not necessarily occur due to local emissions but may be felt at a distant place depending upon the wind direction and other meteorological factors.

The Rourkela Steel Plant is now in the midst of modernisation programme. This programme includes complete replacement and revamping of some out-dated polluting units and installation of more efficient machinery and pollution control devices in other units. These being very costly, will be done in phases and the whole modernisation process is expected to be completed by the end of 1993. A sum of about 150 crore of rupees is likely to be spent on environmental pollution control which is approximately 9% of the total project cost of the modernisation programme. Mere installation of pollution control devices is not enough. Environment will not be protected if they are not maintained and operated properly. It is to be seen how a massive and unweildy organisation, not used to the philosophy of environmental protection in the past, adopts to a new culture after the modernisation is completed.

Rajgangpur near Rourkela is another industrial township which experiences considerable pollution on account of many industries which are air-polluting in nature. The largest and the oldest industry in that area is the Orissa Cement Ltd. (OCL) which produces 34,000MT of portland cement per month. The OCL also has a large refractory unit of production capacity of about 18.000MT/month of refractory bricks of different kinds. Few other cement plants, e g., the IPI SP Cement Plant (capacity 200MT/day) and the Mukund Cement Ltd. (capacity 30 MT/day) are situated within a radius of 15 km from Rajgangpur. Apart from the cement plants, there are three foundries, one spinning mill and one engineering industry in the medium scale sector in and around the town. Although foundries and ceramic plants are considered air polluting industries, the pollution in the area is predominantly by the cement plants, particularly the OCL. The IPI-SP cement plant is situated at a comparatively longer distance and has some pollution control arrangement. The Mukund Cement being a mini-cement plant operating with a vertical shaft kiln (VSK), has a comparatively less pollution potential. In view of these, the OCL can be considered as the main polluter of the Rajgangpur atmosphere The plant was operating till very recently in wet process technology in which the two kiln stacks had ESP's installed to arrest outgoing cement dust, but the ESP's were inoperative. The kiln stacks therefore emitted cement dust at the rate of about 50 — 80 gm/Nm^3 which amounts to about 250 — 300MT per day. Apart from polluting the atmosphere, there was a considerable resource loss on account of this.

The ambient air quality of Rajgangpur does not seem to have been measured in a systematic manner by any agency. The State Pollution Control Board has however made some routine study of the air quality within the premises of the Orissa Cement Ltd The results of the last measurement at three locations are given in Table 11. It is evident that the particulate matter level was sky-high at many places.

Table 11

The Ambient Air Quality of Rajgangpur in OCL Premises

(Concentrations in microgram/cubic metre)

Location	SPM	Sulphur dioxide	Oxides of nitrogen
Canteen building	1260-1920	ND	ND
Weigh bridge (near clay gate)	4,404	43.7	24.6
New colony gate	390.6	34.3	6.2

The OCL has recently changed to dry process for cement manufacture. This process has ESP's for the kiln stacks and other built in pollution control devices. It is believed that the wet process manufacture will be discarded once the dry proces is established. The air of Rajgangpur is therefore expected to be much cleaner in near future than what it was in the past.

The only other town in the State with a large cement plant is the Bargarh town in the Sambalpur district The plant (Hira Cement Ltd situated there belongs to the Industrial Development Corporation (IDC). Unfortunately, the industry continues to operate in the wet process technology without any ESP in the kiln Thus, there is a considerable pollution in the vicinity. The industry however has an objective plan for changing over to the dry process in its future modernisation programme.

There have been a lot of debate obout the health hazards of cement dust The cement lobby puts forward many scientific documents to prove the innocuous nature of the dust Eqally active are the environmentalists to establish its health hazards. Without going into the merits and demerits of both the arguments, it can be said that cement dust is a worst kind of nuisance and can cause asthama and other bronchial problem for those who are prone to such diseases.

Episodal emissions of gases from factories can cause temporary air pollution in an area. The most infamous case was the Bhopal gas tragedy in which thousands of victims died and many more became crippled by the toxic gas, methyl isocyanate (MIC), from a pesticide factory. Small gas leaks have happened in Orissa also The Ganjam NAC area has a large chlor-alkali plant (M/s Jayshree Chemicals Ltd) and some other small units in which chlorine gas is handled. Chlorine gas leaks from those industries have, in the past, caused many public complaints in the area. Because of some recent control measures taken by the Jayshree Chemicals, the frequency and intensity of chlorine leaks have considerably decreased. Episodal emissions of sulphur dioxide and acid mist from a sulphuric acid plant (East Coast Fertiliser and Chemicals Co) at Kalma, Mayurbhanj District had, in the past, caused damages in the neighbourhood. Unfortunately, although the area is a rural area, the density of population there is not less. With the adoption of new technology with pollution control measures, it is expected that the emissions will now conform to pollution control standards. Ammonia gas leak from a small fish processing plant at Kalupadaghat,Ganjam district has resulted in the death of a few workers about a year back. Ammonia is normally not a toxic gas, yet deaths occurred because its concentration in the work environment was too high and therefore, became hazardous. It could have happened due to the negligence and ignorance on the part of the manager and the workers of the industrial unit. Serious gas leaks have occured in the heavy water plant at Talcher Most of the gas leaks can be attributed to improper maintenance of plants and machinery and inadequate disaster management plan. It is also equally true that, in some cases, gas emissions occur due to disruption of power supply. For example when electric power trips without notice, the compressors, pumps etc. in an industry fail so that any gas present in the manufacturing line develops pressure and tends to escape through valves, joints etc. Thus, ***uninterrupted and adequate power supply is a very essential safety requirement for an industry.***

Air Pollution in Mining Areas

Mineral wealth is one of the main natural resources of Orissa. Iron ore, manganese ore, chromite. bauxite and coal deposits are found extensively in the State. Mining activities are, in fact, considered as important causes of envirnomental degradation. The problems associated with mining activities are many. They are : (i) deforestation and the resulting ecological

imbalance, (ii) damage to landscape due to abandoned open cast mines and mine debris heaps which may cause further damage to the environment like soil erosion, (iii) disturbance of underground aquifers affecting flow of water in mountain streams, (iv) air pollution caused by mining activity, movement of vehicles, blasting of rocks etc., (v) water pollution due to mine drainage water, (vi) seismic hazards due to underground mines and (vii) socio economic effects. The present report limits only to the air pollution aspect in relation to the effect of mining activity on the ambient air quality.

The air pollutants generally expected in a purely mining area are suspended particulate matters (consisting of dust, ore fines etc) and oxides of nitrogen (coming from blasting process and automobile emission) Sulphur dioxide is not very much expected in the atmosphere. If, however, mineral processing units are present near the mining site, other types of pollutants may also be found.

The air quality around the iron ore mines in Keonjhar district has been studied systematically at six selected sites by Prof. A. K. Shah and his team belonging to the Centre for Study of Man & Environment, Calcutta as a part of a project work assigned to them by the mining department of the Government of Orissa [*19*]. The study was carried out three times a year (1987-88) on seasonal basis In each season, the study was undertaken for two months with a monitoring frequency of twice a week. Each run was for 24 hours consisting of three 8-hourly shifts. The findings were as follows.

Sulphur dioxide was not found above detectable level except in some sporadic observations. The concentration of oxides of nitrogen was mostly well within the permissible limit (vide Table 12) except sometimes at Daitari and Joda towns in winter. The main pollutant was therefore the particular matters, the concentration of which exceeded by far the permissible limit, particularly in the winter months. As expected, air was mostly clean during rainy season and fairly polluted during winter season. The summarised values of SPM and Knox concentrations at the six stations are given in Table 12.

Table 12

Air Quality of Some Mining Areas in Keonjhar District [*19*]

(All values in microgram/cubic metre)

Station	Suspended particulate Range	Matters Mean	Oxides of Nitrogen Range
Daitari	18.8-1081	189.6	1.6-64.1
Gandhamardhan	12.6-480.5	132.1	2.1-24.4
Joda East	0.8-546.3	138.5	BDL*-18.1
Thakurani	26.3-7024	732.9	BDL*-28.3
Jilling Langalota	7.8-400.9	107.3	3.3-29.2
Joda Township	13.4 400.7	109.5	1.6-46.0

* BDL—Below detection level

Air quality in other mining areas has not been studied in as much detail as has been done in the case of iron mines in Keonjhar The State Pollution Control Board has nevertheless done routine analysis of air in coal mining areas of Rampur of Sambalpur district and Talcher in Dhenkanal district. The findings are similar in that the pollution is mainly due to suspended particulate matters. Much cannot be said in the absence of continuous and regular monitoring data. Another nuisance is observed near coal mining areas due to domestic use of coal. Because of easy availability, almost every household uses coal for cooking and other domestic purposes The fumes from the burning coal cause considerable discomfort in the area, particularly in winter seasons when the fumes do not easily disperse due to meteorological conditions. This situation is very clearly visible during winter months in Brajaraj Nagar and Belpahar areas of Sambalpur district. A possible solution to this could be the supply of coke briquettes to the inhabitants of the area at subsidised rates.

Vehicular Pollution

Automobiles have to-day become an important source of air pollution in the urban atmosphere. Even developed countries which have been somewhat able to control air pollution from industries by improved technologies, find the vehicular pollution almost uncontrollable.

Apart from carbon dioxide, which we will not consider as a pollutant for the present, the automobile emission contains carbon monoxide (a product of incomplete combustion of fuel), bydrocarbon (petrol/diesel and lubricant constituents which are not combustioned), smoke and nitric oxide (a product of high temperature reaction between nitrogen and oxygen of air which invariably takes place in internal combustion engines).

Carbon monoxide is a known poisonous gas. It is the most imporant toxic constituent of auto-exhausts. Smoke is also an accepted nuisance. Besides it contains organic compounds some of which are toxic and carcenogenic.

Nitric oxide produced from the internal combustion engines, when released into the atmosphere, slowly gets converted to brown nitrogen dioxide gas in the presence of air. The mixture of nitric oxide and nitrogen dioxide is referred to as *Knox* (NO_x) as already mentioned. Nitrogen dioxide being a coloured gas absorbs sunlight and initiates photochemical atmospheric reaction chains. These photochemical reactions in the atmosphere are propagated in the presence of substrates like hydrocarbons, carbon monoxide, sulphur dioxide etc which themselves are atmospheric pollutants. As a final consequence of these atmospheric reactions, a large number of complex organic substances are formed-many of which are toxic in nature. These are called the *secondary pollutants.* One such important toxic secondary pollutant is peroxyacetyl nitrate (PAN) which is the main eye-irritant present in urban atmosphere. It is established that *the phenomenon of photochemical smog formation in metropolitan urban areas is due to atmospheric reactions involving mainly knox, hydrocarbons and oxygens* (NO_x - HC - O_2 reaction) [20]. The primary cause of this is the automobile exhaust.

Heavy metals like lead are also present in trace amounts in automobile exhaust gases because of the chemicals like lead tetraethyl added to petrol to improve its ignition property. Lead tetraethyl acts as an "anti knock" agent. Heavy metal compounds naturally tend to settle in the bottom most layer of the atmosphere at the breathing level due to their high density. Heavy metals are well-known toxic substances.

It is often not realised that exhausts of petrol driven vehicles are more hazardous than those of diesel-driven vehicles because they contain more carbon monoxide. Diesel-driven vehicles however produce more smoke. Similarly

emissions from two-stroke engines (mopeds, scooters, motor cycles etc) contain more pollutants than from four-stroke engines both because of the lubricant added to fuel and inefficient combustion in the engine of the former.

Almost no attention was paid to vehicular pollution control in India till recently. The Environment Protection Act, 1986 put the responsibility of laying standards for vehicular emissions to the Central and the State Pollution Control Boards so that those standards can be incorporated in the appropriate Motor Vehicles Acts and Rules. The standards notified by the State Pollution Control Board are the same as those of the Central Bcard.

Accordingly, the Orissa Motor Vehicle Act and Rules have been amended. Implementation will be done by the transport department soon through its officers like the Motor Vehicle Inspectors (MVI's) or the Regional Transport Officers (RTO's). The out come of the legislation is anybody's guess.

Table 13

Standards for Vehicular Emission

(i) Diesel Driven Vehicles

For every motor vehicle powered by diesel engine (compression ignition), the smoke density of the exhaust smoke shall conform to the levels given below.

(a) Vehicle at the manufacturing state — 60 Hatridge Smoke Units (HSU)

(b) Vehicle on road — 70 Hatridge Smoke Units (HSU)

(ii) Petrol Driven Vehicles : Emission Limits for Carbon Monoxide (Percent by volume)

Category	Vehicles on Road	Vehicles at Manufacturing State
(a) Two and three wheeler vehicles with engine displacement less than 50 cubic centimeter (cc)	5.0	5 0
(b) Two or three wheeler vehicles : All vehicles except those in category (a)	4.5	4 5
(c) Four wheeler vehicles e.g., cars, jeeps, light commercial vehicles	4.0	3.5

There has been a substantial rise of the number of motor vehicles including two-wheelers in our towns as can be seen in Table 14 Table 15 gives the number of vehicles in some selected metropolitan cities of India for comparison. Considering the number of vehicles on our roads, air pollution by vehicular exhausts may not have become very serious in Orissa as yet. However, it may become a cause of concern in not-so-distant future if the present trend of the increase of motor vehicles, particularly scooters, motorbikes and mopeds, continues Even to day some stretches of road like the Bhubaneswar-Cuttack road, which has one of the highest traffic densities in the country, do have air pollution problem. Motorists and scooter riders sometimes complain of headache when they drive along the road during peak traffic hours. This is most likely due to inhalation of carbon monoxide.

Table 14

Number of Motor Vehicles Registered in Some Selected Towns of Orissa [*21*]

Place	Year	2-wheelers	Light Motor Vehicles	Heavy Motor Vehicles	Total
Cuttack	1978	7,273	7,307	8,774	23,354
	1987	28,979	11,049	14,812	54,840
	1988	34,975	11,364	15,091	61,430
Bhubaneswar	1978	3,652	752	754	5,158
	1987	24,499	5,079	2,823	32,401
	1988	31,419	5,604	3,113	40,136
Rourkela	1978	10,460	2,663	1,735	14,862
	1987	33,138	5,274	2,634	41,046
	1988	39,130	5,513	2,700	47,343
Whole State	1978	35,294	22,790	49,746	87,830
	1987	1,55,817	37,539	50,158	2,43,514
	1988	1,91,803	39,426	51,688	2,82,917

Table 15

Number of Motor Vehicles in Some Selected Cities of India [22]

Place	No. of Vehicles (X 1000) 1977	1987	Place	No. of Vehicles (X 1000) 1977	1987
Bombay	245	524	Ahmedabad	68	314
Calcutta	147	370	Kanpur	32	122
Delhi	389	1,112	Jaipur	34	146
Madras	69	276			
Bangalore	109	329			

A survey was made by M/s. Motor Industries Co (MICO), Bangalore on the status of vehicular exhaust (with respect to carbon monoxide only) at Bhubaneswar during Dec 12-17, 1988. Of the 266 diesel vehicles monitored during the survey, 55 numbers were found to emit carbon monoxide beyond the permissible limit. Similarly 33 and 20 numbers of petrol-driven two - and four-wheelers, out of the total of 266 and 38 numbers respectively, emitted higher levels of carbon monoxide. In other words, 20.7% of diesel vehicles, 12.4% of petrol-driven two-wheelers and 52.6% of petrol-driven four-wheelers are polluting in nature [23]. The finding that the petrol-driven four-wheeler vehicles have the maximum proportion of polluting ones is not surprising because most of the old vehicles plying on road are private cars or taxis run by petrol.

A perusal of Tables 14 and 15 shows that there is a proliferation of two- and three-wheeler motor vehicles in the state and the country since last few years. It is expected that by the turn of the century, we will have more scooters, motor-bikes and mopeds in the country than the number of bicycles at the time of Independence This is no doubt an indication of economic prosperity of the urban middle class. As already mentioned, two-stroke motor vehicles are more polluting in nature. Thus, it appears that in spite of our concern about vehicular pollution, its level in the urban atmosphere will keep rising because of the continuing rise of the number of two-and three-wheeler motor vehicles. These vehicles are basically unstable ones. The road accidents in our cities are increasing on account of this. Yet the demand for such vehicles remains unabated - so much so that people are prepared to buy some popular brands of scooters with a premium. Why is it so ? It is mostly because our public transport system is in shambles. Mainly because of this, people are forced to have their own modes of transport which they can afford. ***Unless the public transport system is improved, pollution in the urban atmosphere, as well as, accident rates in the streets will be in the rise not withstanding all our efforts for their prevention.*** In this respect, the example of the Peoples Republic of China is worth following. It has an efficient public transport system and therefore, the streets of Chinese cities are not choked with motor vehicles like ours and the urban atmosphere is cleaner.

Pollution from Domestic and Other Minor Sources

The WHO definition of air pollution based on outdoor concentration of pollutants mentioned earlier in this section does not hold good in Indian conditions. In India, maximum amount of toxic pollutants are inhaled within the households by the women folk who squat in front of their chulas inside ill-ventilated kitchens to prepare the family meals. Firewood, cowdung cakes, agricultural wastes etc are used as fuel in these chulas. Burning of such fuels generate almost equal or more carbon monoxide, sulphur dioxide, oxides of nitrogen, organics and particulate matters than the burning of other commercial fuels like coal and petroleum. It is because about 50% of the total energy consumed in India is for cooking purposes and over 9[illegible]% of cooking energy comes from noncommercial fuels like firewood, animal dung etc [*24*]. A recent estimate puts that in 1987-88 the consumptions of coal and oil were of the order of 9.8 & 1.2 million tons respectively in Orissa. As against this, the consumption of firewood was about 11 million tons. Although no statistics is available for the consumption of animal dung and agricultural wastes for fuel purposes, their annual production is estimated as 4.2 and 1.27 million tons respectively [*25*].

A study has been made by the East-West Centre of Hawai on the actual dose of pollutants inhaled during cooking by the women folk in some Gujarat villages. The findings were

Fig 12 A common scence near road construction sites.
Source : Calendar of CPCB, 1987

shocking The average exposure of women to total suspended particulates (TSP) in their cooking period ranged from 1, 110 to as high as 56,600 micrograms per cubic metre. The average value was about 7000 micrograms per cubic metre. This is fourteen times more than the 8-hour Indian standard of 500 microgram per cubic metre for industrial areas (vide Table 6). According to the same study, a Gujarati village woman gets an annual dose of about 4,200 micrograms of benzo-alfa-pyrine (BaP)-a highly toxic and carcenogenic chemical present in smoke - during cooking [26] This has serious health effects on women.

So much so about hazards of domestic cooking in the houses of poor Indian villagers There are also many other places where poor people, particularly women, are exposed to dangerous air pollution in work environment. It is a common sight that road construction workers work with pitch, molten in open vats. Pitch volatiles are considered highly dangerous As can be seen in Table 7, its TLV value is only 0.2 mg/cu metre which is the lowest value of TLV of substances listed in the table. Another common example is the scene near the stone crushers. Most stone crushers use crushing machines without any cover or any other dust control device. The workers—mainly women—work without any protective device like face mask. Consequently they are exposed to stone dusts which cause an incurable disease called "silicosis". The workers working in stone crushers often die early.

The above are only a few examples of serious air pollution to which poorest section of of the society are exposed. While we take all precautions to prevent and control pollution by industries, we are helpless to protect a section of our poor countrymen from the worst kind of pollution hazard.

Noise Pollution

Noise is unwanted and annoying sound. It causes physical discomforts and therefore, can be called as an environmental pollutant Further, since normal sound is nothing but movement of a mechanical wave propagating through the elastic and continuous material medium of air by compression and rarefaction, noise also can be regarded as an air-pollutant Attempts are now being made to incorporate provisions of noise pollution control in the existing Air (Prevention & Control of Pollution) Act, 1981 and Environment Protection Act, 1986.

Depending upon the intensity and duration, a person exposed to noise may suffer from noise-induced hearing loss which may be temporary (temporary threshold shift) or permanent. Prolonged exposure to excessive noise may also cause other pathological and physiological disorders like interference with speech, communication and sleep, annoyance, loss of working efficiency, fatigue, nervousness, irritability, nausea and increase of blood pressure.

The most commonly used unit for noise measurement is the ***decibel (dB) unit***. All common noise experienced have values between 0 to 130 in the decibel scale. The loudest voice heard by human ears was due to the volcanic eruption of Krakatoa that occurred in 1883. It had a value of about 190dB.

Unlike other air pollutants, no standard has been laid down in India for control of noise pollution. It is certainly a difficult task in the Indian context because of our cultural and religious practices. In fact, very few countries to-day have legal standards for noise pollution but upper recommended levels of noise for different categories have been laid down in some advanced countries. The recommended noise levels in the UK are given in Table 16.

Table 16

Tolerated Noise Levels in the UK [*27, 28*]

Type of Noise	Tolerance Limt/dB (A)	
Main Roads	**Day**	**Night**
Basic noise level	70	65
Frequent peaks	80	70
Infrequent peaks	90	80
Commercial Zones		
Basic noise level	60	50
Frequent peaks	70	60
Infrequent peaks	75	65

Indian roads, market areas, factory premises and even Government offices are mostly noisy. Religious functions, social ceremonies, political rallies etc add to the already noisy conditions of our roads and market areas. Yet systematic studies of noise levels are very few. As far as known to us, there has been only one systematic study in Orissa on noise pollution. Dr. T. N. Tiwari and Sri M Ali of the Regional Engineering College, Rourkela have measured the traffic noise level in the month of July 1988 at 15 locations along the main ring road and at 13 locations in other roads of Rourkela city [*27*]. They have also measured the noise levels in some commercial areas of the steel township (13 locations) and the civil township (8 locations) of Rourkela [*28*]. Their findings are summerised in Table 17.

Table 17

Noise Levels in Rourkela City [*27, 28*]

Traffic Noise Area	Overall Sound Pressure Level/dB(A) Min.	Max.	Av.
Ring road	62.8	110.4	74.9
Other roads	65.4	103.6	79.9
Noise in Commercial Areas			
Civil township	69.8	103.6	82.3
Steel township	53.6	93.3	70.5

The results can be compared with the recommended noise levels of the UK in Table 16 to get a relative idea. It is evident that the noise levels in commercial areas are more than that in the UK. Rourkela is a planned city. The situation may be worse in other unplanned towns like Cuttack, Berhampur and Sambalpur.

A comparison of traffic noise of Rourkela with that of other metropolitan cities in India and the World (Table 18) shows that the problem of traffic noise at Rourkela has not yet become very serious This should not give any sense of relief or complacency because the traffic density of Rourkela is much less compared to that of other cities listed in the table.

Table 18

Comparison of Traffic Noise of Rourkela with Some Other Selected Cities in India and Abroad [27]

City	New York	Washington	Paris	London
Noise Level (dB)	100-120	90-110	80-160	100-160
City	Amsterdam	Frankfurt	Copenhagen	Brussels
Noise Level dB)	90-170	110-170	120-160	110-150
City	New Delhi	Bombay	Calcutta	Rourkela
Noise Level (dB)	110-160	100 180	90-170	60-110

Surprisingly the study team has not chosen to measure the noise level in the industrial premises of Rourkela. Industrial noise is particularly more harmful than traffic and other noises that are generally experienced in urban areas.

Survey of noise levels in all other towns of Orissa should also be carried out.

Conclusion

A few general conclusions can be drawn from the foregoing discussions in the section. They are

* Because of low level of industrialisation, air pollution has not attained serious proportions in the State except in some industrial pockets and mining areas (e.g., Talcher-Angul, Rourkela-Rajgangpur, Daitari). In these areas, the main pollutants are particulate matters and not oxides of nitrogen and sulphur.

* In the absence of large metropolitan cities, vehicular pollution is less in Orissa in spite of the existence of large number of old motor vehicles. This, however, may not be true in some areas of heavy traffic density (e. g., Bhubaneswar-Cuttack road).

* The maximum hazard of air pollution is experienced by the poorest people, particularly women, in their kitchens or work places (road construction, stone quarry, stone crusher etc). ***Solution to this lies in the general eradication of poverty which appears as a distant cry at the moment.***

OUR DECREPIT MONUMENTS

Orissa is famous for temples of exquisite architecture built mostly between the seventh to the thirteenth century. The most famous of them are the Jagannath temple of Puri, the Lingaraj temple of Bhubaneswar, the Rajarani temple of Bhubaneswar and the Sun temple of Konarak. The erotic sculptures and the fine carvings of the Sun temple are world famous and attract a large number of tourists every year. The Jagannath temple is one of the five most important places of worship for Hindus.

Unfortunately, the Sun temple of Konarak, hailed as one of the best specimens of Indian architecture, remained in a state of neglect till 1900 AD. Although a comparatively younger temple, built by King Narasimha Dev (1238-64) towards the middle of the thirteenth century, this temple has suffered both due to natural environment, being within 3km from the sea coast, and the greedy hands of man The damages observed in Orissan temples are of two types : (i) structural damage and (ii) damages of the exquisite fine carvings and sculptures.

Every edifice has its own life cycle and grows old with the ageing of the component materials. Every monument therefore decays with time. The rate of decay depends upon many factors like the material with which a monument is built, how and where it is built, the environment to which it is exposed and human use or abuse These factors are either "intrinsic" or "extrinsic". The intrinsic factors are mainly due to inherent weakness in the structure such as the ground on which it rests, the constituent elements (materials) with which it is made of and the building system (engineering design and execution). The structural damage is mainly due to intrinsic factors. The extrinsic factors may be natural with long term effects or artificial, caused by human abuse.

The Decay of the Sun Temple at Konarak

The deterioration of the Sun temple has been an object of controversy in recent years which has been highlighted by most of the national newspapers [*29*].

Various speculations have been made as to the possible cause of the collapse of the "*shikara*" of the sanctuary of the main temple. Some ascribe it to the subsidence of the foundation and others to a shock of earthquake or lightening; some again doubt if the temple was ever completed. Renowned experts have examined all the theories but nothing has been conclusively proved. Probably with the removal of the enshrined image to Puri, the structure fell into utter neglect and crumbled down gradually[*30*]. The situation was further worsened by the vandalism of the local zamindars and the inhabitants who carried away some stones to build their own houses.

Although it is almost certain that the main cause of the decay of the temple was the structural collapse due to intrinsic factors, further weathering of stones occurred which were particularly harmful for the sculptures and carvings. In this process, the environment (atmospheric conditions) was the main contributing factor. Being located near the sea, the stones were subject to weathering agencies like saline sea wind and sand blasts. Furthermore, due to heavy rainfall and moist conditions around, there was growth of moss and lichen on the stones. At one stage, the entire temple—or rather the temple ruin, was so much covered with black vegetational accretion, that it came to be known as the "***Black Pagoda***" [*31*].

Mainly three types of stones have been used in the Konarak Sun temple, viz. khandolite, red laterite and Athgarh sandstone Khandolite is the main stone used to carve out the sculptures. This rock is distinctly banded. The different bands have different mineral composition and naturally have different corrosional or erosional behaviour to weathering agents in the environment It has beeh observed that the highly quartzose bands have withstood weathering better than the highly garnet, ferrous and felspathic bands, the last being the most susceptible one. It appears that the khandolite stone is rather prone to weathering. The weathering action takes place in many ways, viz. (i) chemical corrosion (hydration, hydrolysis, solution and leaching), (ii) crystallisation of soluble salts, (iii. abrasive action of sand bearing wind and (iv) biochemical (growth of moss and lichen.)

The Archaeological Survey of India (ASI), which is entrusted with the work of conservation and restoration of the temple, has taken certain definite steps in the direction. There is, however, some controversy as to whether they have taken the right steps in the most scientific manner based on a thorough study. Certain steps taken like the removal of sand dunes, close to the temple, filling of interiors, erection of dry masonary walls inside the "*Mandapa*" have not been questioned. The doubts raised are about the inadequacy of environmental study before taking up the restoration work, particularly of the fine carvings.

The Government of India had appointed a committee of experts in 1950 to go into the whole question of preservation of the monuments and to find out appropriate measures for prolonging their life. The principal recommendations of the committee were (i) testing of the humidity contents inside the sealed porch of the "*Jagmohan*", (ii) making the entire temple water tight from outside by grouting, filling in of joints, rectification of wrong slopes and

Fig 13 Differential weathering of a sculpture in the Sun temple

(This sculpture has been carved out of two stones. Greater erosion is observed in the lower stone.)

concreting the tops of the irregular masonary, (iii) removal of sand from the compound with necessary provision for drainage of water, (iv) rebuilding of the damaged compound wall to the height of the original coping, (v) chemical treatment of the surface and (vi) planting a thick belt of casurina and cashew nut trees in the direction of the sea so as to produce a screening and sheilding effect for the temple, both from sand drift and the consequent attrition [32]. The ASI claims that continuous conservation measures are being taken as per the recommendations and further that a team of UNESCO experts visiting

the monument in 1981 and 1987 have endorsed the measures taken.

Dr C. R. Das, Department of Chemistry, Ravenshaw College, Cuttack, who is an expert on corrosion and erosion, has questioned the methods adopted by the ASI for preservation and restoration [*33*]. He carried out certain experiments *in situ* to study the nature and extent of corrosion damage Mild steel and titanium steel strips were placed very close to the Sun temple and the rate of corrosion was measured by weight loss of samples in monthly intervals for a year. The nature of damage was studied by sophisticated scientific methods (X'ray, SEM etc). His findings showed that the rate of corrosion is maximum during rainy days when the humidity of the atmosphere is high The salt (chloride ion) present in the atmosphere gets dissolved in the rain water and then gets deposited inside the pores of the stones. This accelerates the corrosion process, particularly on the iron clamps used inside. These iron clamps were used for holding the stones, little realising at that time, that these very clamps, in the long run, will promote disintegration of the stones due to corrosion of the metal. It was also observed by Dr Das that dissolved gases like carbon dioxide, sulphur dioxide, oxides of nitrogen etc have profound effect on the corrosion/erosion rate. The increase of carbon dioxide in the atmosphere and also the possible increase of oxides of nitrogen near the temple due to rapid increase of vehicles in recent years could also have influenced the weathering procees which has not been examined. Other factors like wind direction, aerosol content in the atmosphere, temperature gradient etc are also important in determining the rate of weathering Probably, all these environmental aspects have not been examined while preparing for the execution of the restoration work on the sculptures. In fact, the ambient air quality and the micro-meteorology of the Konarak area has not been studied in any detail so far.

Dr Das has even questioned the usefulness of some of the methods of preservation carried out by the ASI. Patchwork cleaning of the stone carvings with ammonia solutions and sometimes with solutions of zinc silicofluoride with the help of tooth brushes has been particularly criticised by him.

These observations have been objected to by the ASI which puts forward various reports, including that of UNESCO, in favour of their methods. It is further claimed that Dr Das perhaps has not taken into consideration the nature of the stone which is particularly prone to weathering [*32*]. The views of Dr Das and the ASI have been presented here for the best judgement of the reader. Dr Das's views would have acquired better credibility had he suggested alternative measures for restoration. This controversy, however, makes one believe that perhaps a greater input of research is necessary to know the exact mechanism of weathering of the fine sculptures.

The following important point emerges from the foregoing discussions. Table 6 gives the ambient air quality standards for sensitive areas which include areas having archaeological monuments. If we look at the ambient air quality of a highly industrialised area like Angul-Talcher discussed earlier in this report, the levels of pollutants like oxides of sulphur and nitrogen are well under the prescribed values for sensitive areas. It is therefore very likely that areas like Puri and Konarak, which are not industrialised, do not have air-pollutants above the limit or even near it. But these areas being close to sea, even very small amounts of air-pollutants will have cumulative effect on the monuments and the corrosion will be more pronounced. Moreover, already weathered stones of the monuments which have lost their resistance, will be more prone to environmental corrosion and erosion compared to freshly cut stones. Thus, there is a strong case for very

strict ambient air quality standards than those given in Table 6, for areas having old monuments in marine environment.

Conclusion

In conclusion one may say that although the damage of the Sun temple has been primarily due to intrinsic factors like structural defect and inherent weakness of the stone used, environmental factors which have played an important role in the weathering process have not been thoroughly examined. It is not to say that deterioration of the monument could have been arrested otherwise, but at least there would not have been any uncertainity and doubt about specific measures calling for suitable action. We should not allow the same experience of Taj Mahal to be repeated near Konarak and other archaeological sites. Nobody had bothered to study the air quality of Agra town when a large number of foundries and the railway yard were established in the town and a giant refinery came up in the nearby town of Mathura until the famous Taj Mahal showed definite signs of rapid deterioration.

The immediate need of to-day is to regularly monitor the air quality and the meteorological data at Konarak, Puri, Bhubaneswar and other places of archaeological importance to keep a close watch on the level of pollution and change of meteorological parameters. Establishment of a small ambient air monitoring centre at any place is not an expensive proposition Further, *no polluting industry should be allowed to come up in ard around places of archaeological importance* - to start with at Puri, Konarak and Bhubaneswar. Industry and archaeology need not co exist because, more often than not, they affect each other adversely.

It is also recommended that the choice of plant species for development of green belts around archaeological monuments should be done very carefully to include pollution-indicating and pollution abating varieties.

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